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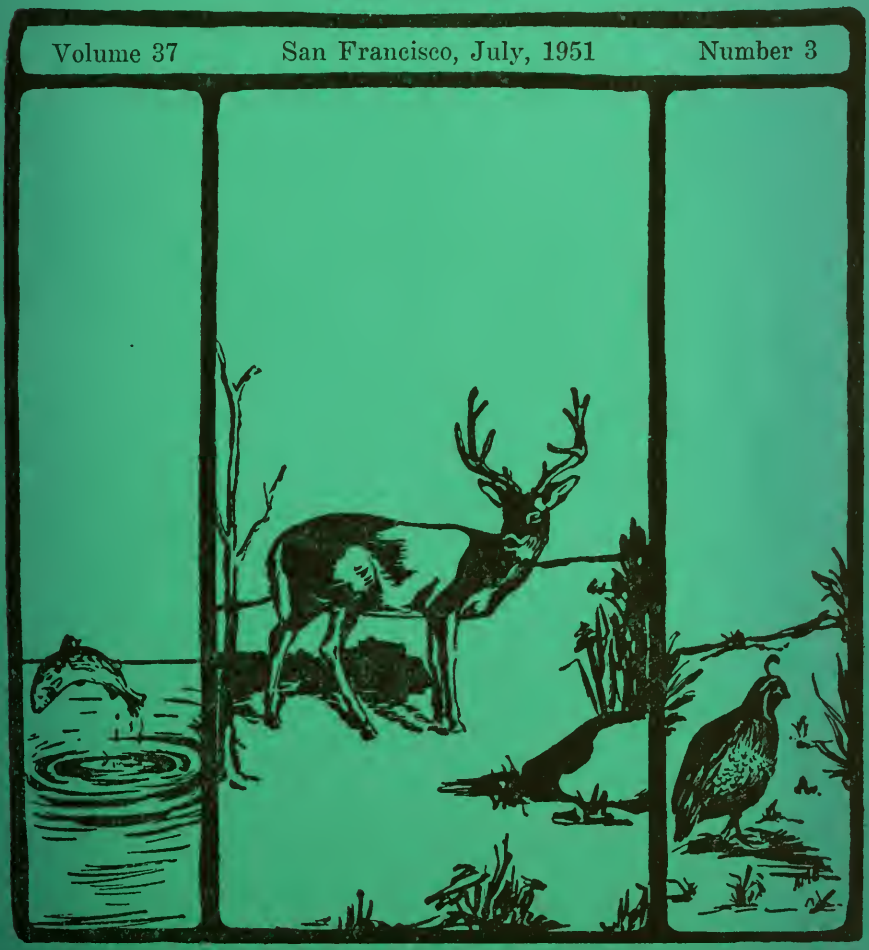

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CALIFORNIA FISH and GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

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THE DEVILS GARDEN DEER HERD [1]

(FIFTH PROGRESS REPORT OF THE INTERSTATE DEER HERD AND ITS RANGE, INCLUDING A SUMMATION OF WORK TO DATE)

By Interstate Deer Herd Committee

INTRODUCTION

The Devils Garden interstate deer herd is made up of Rocky Mountain mule deer (*Odocoileus hemionus hemionus*) that summer principally on the Fremont National Forest in Oregon and winter on the Devils Garden area in the Modoc National Forest in California. The Oregon summer range covers approximately 400,000 acres and the California winter range approximately 335,000 acres. Much of the area that is classed as winter range, however, is made up of territory through which the deer merely pass during migration. The acreage on which the deer spend the greater part of the winter is much smaller, covering approximately 100,000 acres (Figure 94). In addition to the animals from Oregon, a considerable number of deer from summer ranges in California also come to winter on this smaller area (Interstate Deer Herd Committee, 1949a).

Earliest records of livestock use of the Devils Garden range extend back to 1870. During subsequent years the range was heavily stocked. It has been estimated that by 1900, there were approximately 75,000 cattle and horses using the area bounded by Mt. Dome on the west, Goose Lake on the east, and Mud Lake on the south. The thousands of horses which remained on the open range all winter were particularly destructive of the native vegetation.

In the 1880's sheep grazing began. The area became noted as a winter and lambing range. The peak in sheep use was reached between 1916 and 1920, when an estimated 125,000 of these animals were present on the area between Mt. Dome and Doublehead Mountain. The range is capable of supporting only a fraction of that number today.

Part of the winter deer range came under responsible administration when the Modoc National Forest was created in 1904. But the most of the deer midwinter concentration area remained public domain until 1920, when it was added to the national forest. Since that time livestock has been greatly reduced. At the present time, limited numbers of cattle and sheep are permitted on the Devils Garden range during the regular spring-fall grazing season.

Deer were reported as scarce in the Devils Garden area when John Work passed through on his "Fur Brigade to the Bonaventura" in 1832-33 (Maloney, 1945). Fremont and Applegate reported an abundance of deer in 1846. Older residents claim that deer were numerous until the

[1] Submitted for publication February, 1951.

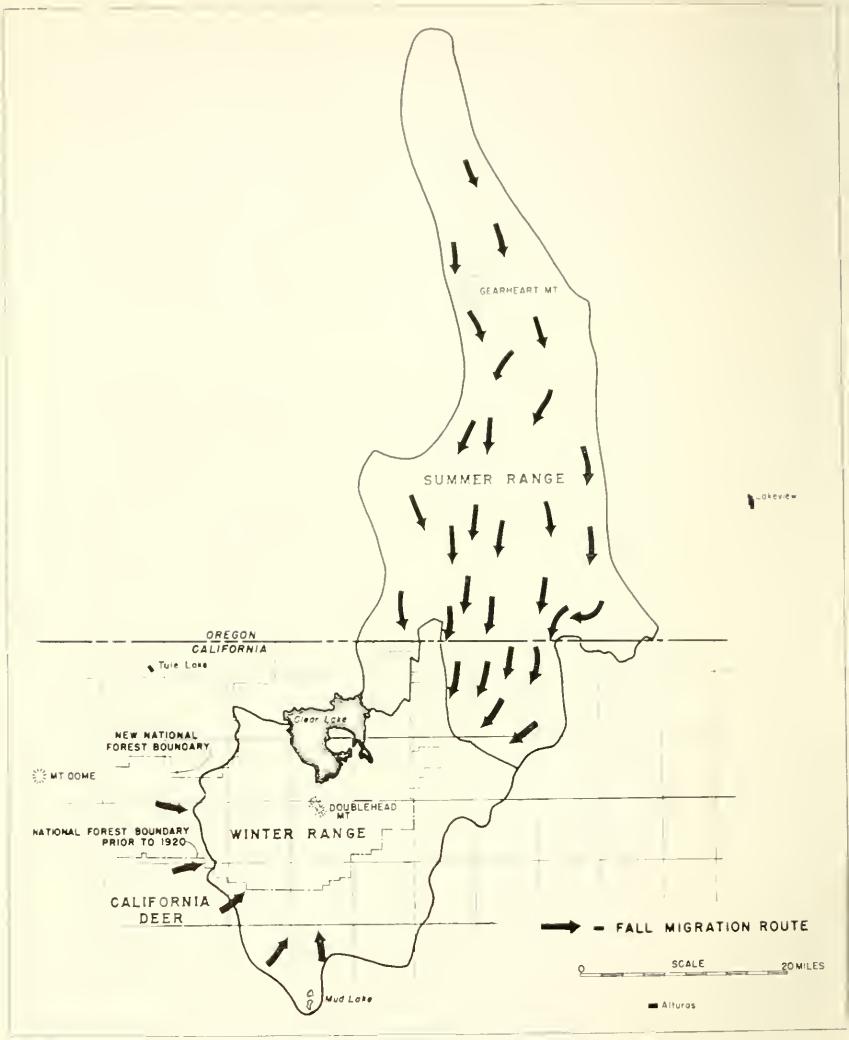

FIGURE 94. Location of the summer and winter ranges of the interstate deer herd

severe winter of 1889-1890, after which for a time they practically disappeared. Since that time deer have increased.

The forage resource on the Devils Garden area has been depleted considerably by past grazing abuses. Large areas, which once supported stands of good perennial grasses, now maintain principally an annual cover, mostly cheat grass (*Bromus tectorum*).

The better browse species have also suffered. Bitterbrush (*Purshia tridentata*) is the most important browse species on the deer winter range (Hormay, 1943). The bitterbrush stand not only shows the effect of heavy livestock and deer use, but has also been depleted by fire, drought, and to a lesser extent by tent caterpillars and rodent girdling.

FIGURE 95. Deer on the Devils Garden winter deer range. *Photograph by U. S. Forest Service.*

Since 1936, several large fires have destroyed browse species on extensive areas. A fire history map will be found in Figure 96. The severe drought that occurred over the northwest from 1917 to 1936 contributed to the weakening and killing of browse plants on sizable acreages. At the present time there exist thousands of acres on which bitterbrush stands are almost completely dead.

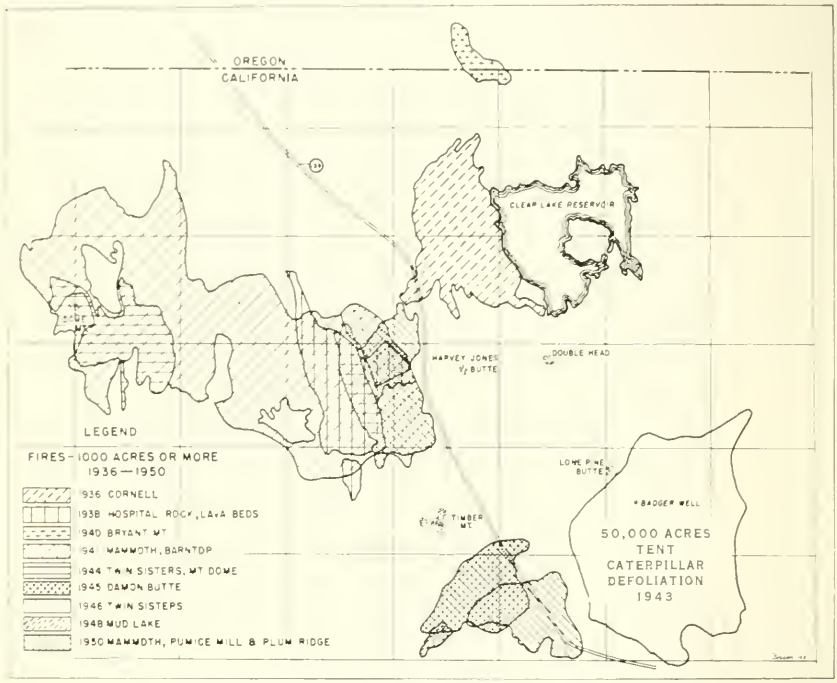

FIGURE 96. Location of areas burned by large fires on the Devils Garden winter deer range. Also shows areas on which caterpillar damage is heaviest.

A deer food problem has been recognized on the Devils Garden winter deer range for many years. Modoc forest officers first observed abnormal cropping of juniper trees (*Juniperus occidentalis*) in 1931. By 1935 this range depletion was a cause of concern to the forest administrators.

The forest service assigned a wildlife technician to study the problem during the winters of 1937-38 and 1938-39. Studies were conducted to determine winter range boundaries, deer numbers, herd composition, feeding habits, and migration routes and dates. As a result, it was reported that an overpopulation of deer was present on the winter range, and that forage productivity and carrying capacity were being seriously reduced by over-utilization of forage plants. Reduction in livestock numbers and the removal of surplus antlerless deer were recommended.

The Oregon Game Commission recognized the need for action by opening the Mule Deer Refuge on the Fremont National Forest and authorizing special antlerless deer seasons in 1939, 1941 and 1943. This resulted in the removal of 4,775 antlerless deer mostly from the summer range of the interstate deer herd.

During the winter of 1943-44, officers on the Modoc National Forest continued their investigation of the deer-range problem. Checks were made of forage utilization, deer herd movements, herd composition and total numbers. They reported that key forage species had been practically eliminated on large areas and that much of the remaining stand was not able to reproduce because of over-utilization of seasonal growth. A reduction of antlerless deer, including deer that remained yearlong in California, was recommended.

In 1945, the Interstate Deer Herd Committee was organized to study the deer-livestock problem on the Devils Garden winter deer range. This committee is composed of members of the Oregon Game Commission, the U. S. Forest Service, Regions V and VI, the California Division of Fish and Game, and representatives of organized sportsmen and livestock growers associations. The findings of this committee have been published in progress reports (Interstate Deer Herd Committee, 1946, 1947, 1949b, 1950) of which this report is the fifth.

The studies of the Interstate Deer Herd Committee resulted in adoption of a plan for management of the Devils Garden winter deer range. This plan set up guides for regulation of both deer and livestock numbers on the winter range. In accordance with this plan, the number of livestock permitted on the winter range by the Forest Service has been reduced. In October and November, 1950, special seasons were authorized in Oregon and in California, which allowed the taking of antlerless deer on both the summer and winter range of the deer herd in order to bring deer numbers into closer balance with the supply of forage on the winter range.

It is the purpose of this fifth progress report to present a summation and evaluation of methods and findings of past studies, as well as an account of recent action and results.

SIZE OF THE DEER HERD

Deer do not lend themselves to accurate censusing. A study made of the effectiveness of various deer census methods indicated that none of the practical methods tested was 100 percent accurate (Rasmussen, 1944). The census methods used in the course of the studies have aimed at approximate rather than exact numbers.

Strip Counts

The first attempt to census the Devils Garden interstate deer herd was made by Randle during the winter of 1937-38. He reported that the occurrence of severe winter weather between March 1-15 forced the deer herd into an area of approximately 25,300 acres (Figure 99a). A count of all deer on 13 random strips covering 5,720 acres resulted in an actual tally of 2,555 head. On the basis of this count of a deer to every 2.2 acres, it was computed that the total deer herd numbered 11,150. Because of reports that some deer had drifted even farther west than the concentration area, Randle considered the actual number of deer in the herd as being in excess of 15,000 head (Randle, 1938).

Strip counts were resumed by the Modoc forest staff during the winter of 1943-44. The winter range was divided into 39 units, each of single vegetation type, as shown in Figure 97. A counting strip was located through each unit. Automobiles were used to count wherever

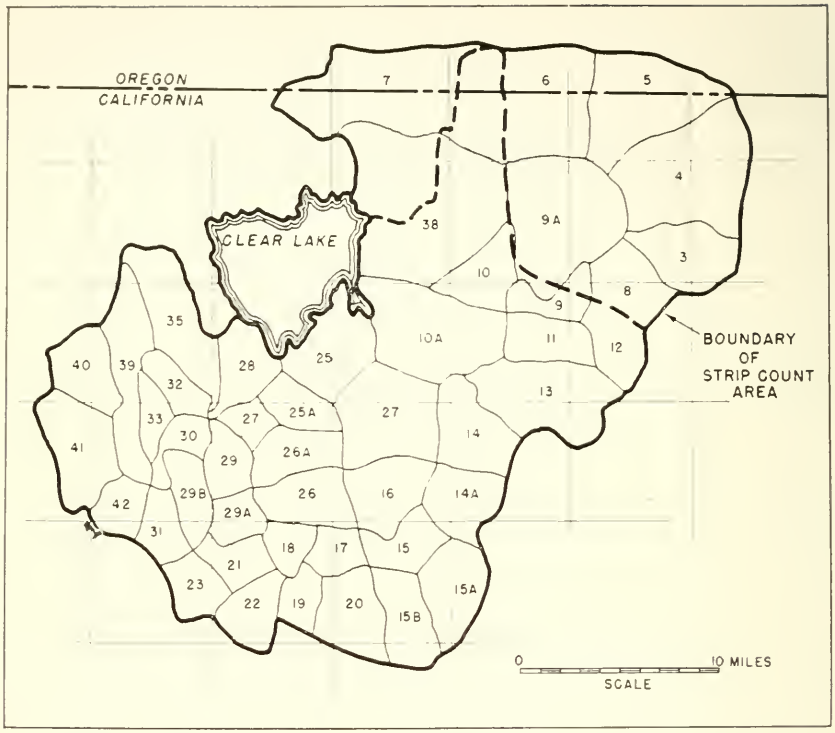

FIGURE 97. Location of strip counting units on the winter deer range study area

possible, otherwise saddle horses were used. Counts were made at 10-day intervals throughout the first winter (Fischer, et al., 1944).

The area of each strip on which deer could be counted accurately under prevailing conditions of cover and topography was estimated. Counts were then converted to deer per square mile and applied to the entire area within each counting unit (Cronemiller, et al., 1946).

Based on the strip counts, the deer population was first reported as 20,700 head (Fischer, et al., 1944) but later recomputed at 18,000 head (Interstate Deer Herd Committee, 1946).

During the following winter (1944-45) strip counts were made in an identical manner, but at monthly, rather than 10-day, intervals. The size of the deer population was reported as unchanged (Fischer, et al., 1945).

The car strip census was continued by the Interstate Deer Herd Committee with some modifications. During the first three winters (1945-46, 1946-47 and 1947-48) counts were made monthly from November to March, inclusive. But examination of the data revealed that January was the month when the deer were most concentrated and during which the highest counts were obtained. During the winter of 1948-49, strip counts were reduced to two (December and January) and to one in 1949-50.

The deer population, as computed from the strip counts, fell from 18,000 to 13,600 the winter of 1945-46, to 12,400 the winter of 1946-47,

and to 9,800 the winter of 1947-48. But all inferences that a severe decline in deer numbers was in progress became shattered during the winter of 1948-49 when the occurrence of heavy snowfalls and low temperatures forced the deer into heavier concentrations similar to that reported by Randle for 1938. As a result, the computed deer population jumped to 23,400 head.

It became apparent that the strip count as conducted in the past could not be relied on to give adequate approximations of the deer population. During mild weather in open winters not all the deer remained inside the boundaries of the study area. On the other hand, it appears that in severe winters, additional deer are forced into the area. The effectiveness of strip counts can vary considerably not only with weather conditions but with the time of day at which they are made. For the Devils Garden counts, men had to assemble from long distances, so dates had to be scheduled in advance. But ideal counting weather could not be so scheduled. Because of the long mileage of counting strips, the count had to be made as rapidly as possible in order to prevent duplicated counts resulting from deer movements. Hence much counting was done at other than ideal times of day. As a result of all these factors, there was discrepancy in the counts. This became even more apparent during the following winter (1949-50), when an incomplete strip count made during February, because roads were impassable in January, resulted in a drop to 10,200 head. Obviously, estimates based on partial counts have little value. A summary of deer population as computed from strip counts will be found in Table 1.

TABLE 1

Devils Garden Deer Population Based on Strip Counts

Winter	Computed deer population	Winter	Computed deer population
1937-38	11,150	1946-47	12,400
1943-44	18,000	1947-48	9,800
1944-45	18,000	1948-49[2]	23,400[2]
1945-46	13,600	1949-50	10,200 (Incomplete)

[1] Open winter, deer scattered.
[2] Severe winter, deer concentrated.

The strip count, as made on the Devils Garden winter deer range, has proven inconsistent as an indicator of the true size of the deer herd. The additional expense that would be involved, were steps taken to correct the weaknesses of the method, would probably make such action impractical. The interstate deer herd committee has recommended that this type of census be discontinued on the winter range.

Drives

Deer drives were tried on a small scale on the Devils Garden winter deer range during two winters (1945-46 and 1946-47). The area driven consisted of about four sections. A regular road strip census was made of this unit during a cold, windy day in March, 1946. No deer were seen. A few minutes later a drive was started, and 307 deer were counted (Interstate Deer Herd Committee, 1946).

Another drive of the same area was made the following winter on a warm, slightly cloudy day in February. Deer were reluctant to leave cover, milled about, and cut back through the drivers, making counting conditions difficult. A total count of 594 deer, or 148 per section, was obtained (Interstate Deer Herd Committee, 1947). Both drives indicated that the strip count method of counting deer is apt to be conservative unless weather and feeding conditions are ideal so that deer are freely distributed, rather than bunched in dense cover.

Aerial Census

An airplane deer count was made in February, 1947. The Devils Garden area was divided into seven units all of which were flown in three days. Strips, at the rate of 2.7 to the mile, were flown at 75 to 300 feet altitude depending on vegetation cover types. Buttes were flown independently in rising spirals. All bands of deer not easily counted were photographed with a "K-20" aerial camera and counted from photographs.

Because no attempt was made to count deer in the timbered areas on the southern portion of the winter range, the census was incomplete. The total count was 4,258 head (Interstate Deer Herd Committee, 1947).

It was reported that deer were easily seen on bare ground and in open brush, and could be readily distinguished on areas of open juniper cover type, but that the animals were hard to see in denser stands of juniper and in lava pockets. The Interstate Deer Herd Committee plans to use the aerial count whenever weather conditions concentrate the deer herd in open terrain.

State-line Track Counts

A dirt road parallels the boundary line between Oregon and California. This road makes a convenient strip upon which to count deer tracks. During the fall migration, there is considerable automobile travel on the road, but in the spring the road remains in large part undisturbed. The Interstate Deer Herd Committee decided to include among its census methods a count of deer tracks made each spring along the state-line road during the northern migration of the interstate herd.

The road has been divided into counting units divided by mileposts or other easily distinguishable features. Each unit is counted every other day during the peak of the migration and less frequently as migration falls off. Counts are made with saddle horses or jeeps. All southbound tracks counted are subtracted from northbound tracks. A brush drag is pulled behind a horse, or a spring-tooth harrow behind a jeep, to obliterate tracks after they are recorded and to prepare the road-bed for the next count.

It has been recognized that the state line track counts give only minimum figures of the number of deer crossing from California into Oregon. It is difficult to distinguish deer tracks where the road surface is hard or rocky. Where bands of deer cross the road in single file, a percentage of the tracks will be obliterated. Snowfalls will cover tracks before they are counted, and rains may wash them out. For these reasons, the observers have reported that counts only indicate that at least that many deer moved across the state line during the counting period.

The first systematic track count was made in the spring of 1947; counting conditions were reported as good. A total count of 10,826 sets of tracks was recorded. To this figure an estimate of 3,058 head was added to take care of (1) animals that had crossed the line before the count was made, (2) animals that crossed after the count was discontinued, (3) animals that crossed west of the counting strips. Of the total obtained, it was estimated that 12,884 were deer that had wintered on the Devils Garden winter deer range.[1]

During the spring of 1948, the counting strips were extended, as shown in Figure 102, to include all migration routes. Adverse weather seriously hampered activities. Snow, sleet, or rain occurred almost daily during the counting period, and obliterated many deer tracks. A total of 9,665 sets of deer tracks was counted. No estimate of additional deer was made.

In 1949, weather conditions were favorable. A net total of 14,011 sets of tracks was counted.

In 1950, the weather conditions were favorable except that a period of continuous stormy weather, between May 1st and 7th, occurred during the peak of the migration. It was estimated that a minimum of 2,000 deer crossed during this week when tracks were not tallied. A total count of 13,256 sets of tracks was recorded.

TABLE 2

Interstate Deer Numbers Based on Track Counts

Year	Actual count	Estimate of number missed	Total
1947	10,826	2,058	12,884
1948	9,665	No estimate	9,665
1949	14,011	No estimate	14,011
1950	13,256	2,000	15,256

Table 2 summarizes the track counts by years during the four-year period. Figure 98 illustrates graphically the number of deer migrating by daily periods.

Because the track count is the only measure of the number of deer that are interstate migrants, and is valuable as a minimum estimate of deer numbers, the Interstate Deer Herd Committee has decided to continue the use of this census method. However, it gives no measure of the number of deer that summer on California ranges.

Deer Pellet Counts

The deer pellet count is more than a census method. The approximate number of deer on a range can be determined by this method. But it has an equal, or more important, value in revealing the portions of a range where deer actually spend their time. By making periodic counts, it is

[1] Not all the deer that migrate from Oregon to California each fall end up on the Devils Garden winter deer range. An unknown number of interstate deer winter in the East Garden. These animals migrate across the state boundary line east of the Devils Garden deer herd counting strips. It is possible that some of these animals winter in the Alturas-Canby rim area. Randle estimated that approximately 14,000 deer wintered in this area during the winter of 1938-39, but field observations indicate that the number of deer has dropped considerably since that time. This deer herd which winters in the East Garden is outside the scope of the present cooperative study.

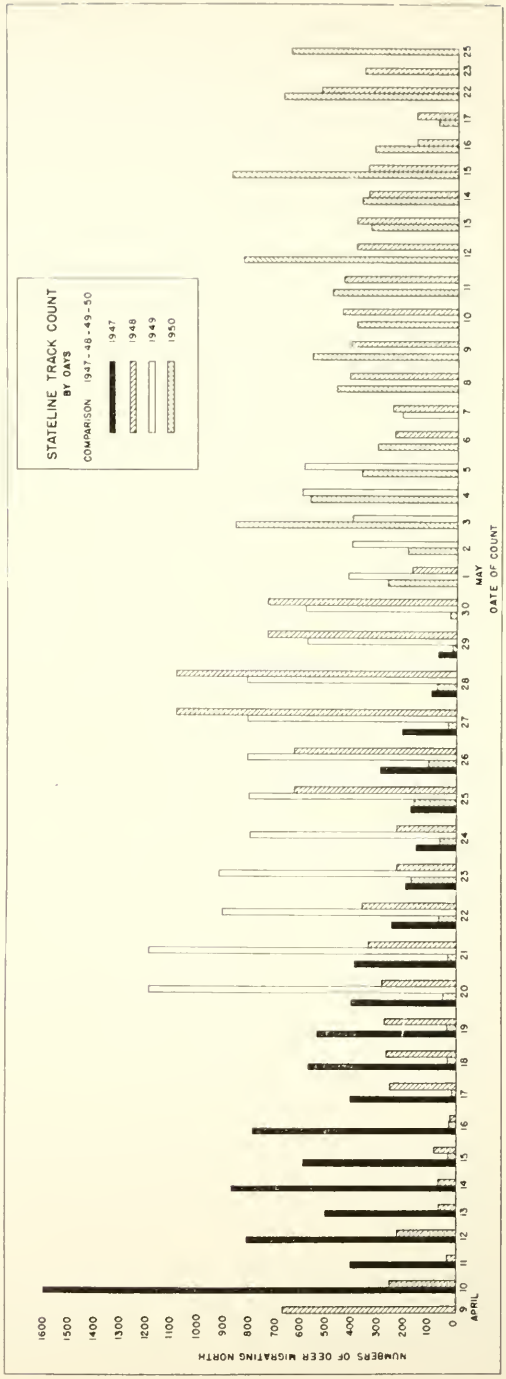

FIGURE 98. Number of deer migrating north by daily periods as indicated by track counts

possible to determine deer movements and concentrations. Also, it is possible, through the use of conversion factors, to determine the approximate poundage of forage consumed by deer during their period of residence.

The method of making deer pellet counts has been described by McCain (1948). Briefly, a system of randomized counting strips is laid out on the unit to be sampled. Fresh groups of deer dung found on the strips are counted. Groups left from previous years are distinguished by color and weathering and not counted. The total count is converted to deer-days by use of a conversion factor of 12.7 groups to one deer-day, as determined by Rasmussen (1943).

Ten thousand deer-days can mean that 10,000 deer were on the range for one day, or 1,000 deer for 10 days, or 100 deer for a 100 days. But if the approximate length of the period that deer were on the range is known, the length of stay can be divided into total deer-days to give the approximate deer population.

Deer pellet counts began on a systematic basis on the Devils Garden area in the spring of 1947. A total of 155 sample plots was counted. Some of the area now classified as summer range was included in the sample unit, and part of the area now included in the winter range was left out, so that the count is not directly comparable with other census figures. A total of 2,054,000 deer-days was computed from the count data. Based on migration dates, the period the average deer spent on the winter range was estimated at 172 days (October 25 to April 15). Using this figure, the total population was computed at 12,000 head of deer.

Figure 99b shows the areas on which deer concentrated during the winter of 1946-47 as indicated by the pellet count. The data indicated that 58 percent of the deer range use had occurred on 48,000 acres leaving the balance of the use spread over 322,500 acres (Interstate Deer Herd Committee, 1947). No counts were made west of the Alturas-Klamath Falls Highway. Subsequent counts show large numbers in this area.

In 1948, pellet counts were made at the sites of the new permanent forage utilization plots in process of establishment on the winter range. The counting strip was fixed at eleven chains long and six feet wide, or one-tenth of an acre. That spring 183 plots, scattered over 338,000 acres, were counted. A total of 3,857,300 deer-days was computed from the count data. The average length of stay was estimated at 192 days (November 1 to May 10), and the total population computed at 20,000 deer.

The areas on which deer concentrated during the winter of 1947-48 are shown in Figure 99c. It was indicated that 79 percent of the deer range use had occurred on 110,000 acres (Interstate Deer Herd Committee, 1950).

The most complete deer pellet count was made in the spring of 1949, when 384 plots scattered over the 338,000 acres of winter range were counted. A total of 5,299,550 deer-days was computed. With an average stay of 184 days (October 25 to April 27), a total population of 28,800 deer was derived.

It was indicated that 45 percent of the range use by deer during the winter of 1948-49 had occurred on 46,400 acres, and 82 percent of the range use on 138,700 acres. Concentration areas are shown in Figure 99d (Interstate Deer Herd Committee, 1950).

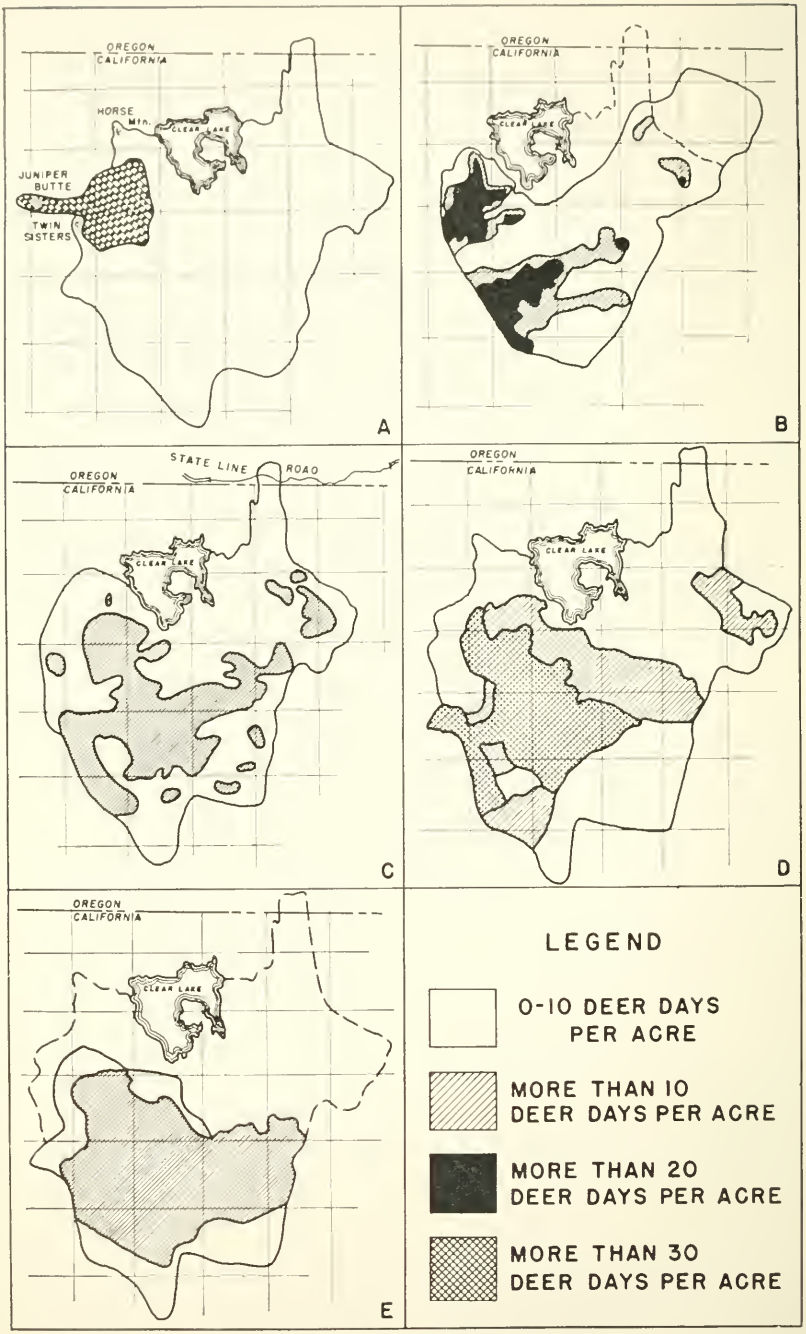

FIGURE 99. Location of areas on which deer concentrated during the years of study. See text for details.

In the spring of 1950, the question of the necessity of sampling the entire winter range each season, when most of the use occurred on a much smaller area, was resolved by limiting both forage checks and pellet counts to what was believed to be the key area. It was decided that a knowledge of trend in deer numbers and deer forage utilization on this key area was sufficient for the deer management program. As a result, the area sampled was sharply reduced and the number of plots counted was only 122.

Because pellet counts were made only at forage plots where key forage species were present, several blanks resulted in the picture of deer concentrations. The Interstate Deer Herd Committee has decided to remedy this defect in the future.

The incomplete count data indicated that deer use on the key area during the winter of 1949-50 was only 80 percent of that of the previous year, if the count data obtained in 1950 is compared with that obtained from the same plots in 1949. The incomplete data revealed that the deer concentration area extended to the east much farther than during the previous year, as shown in Figure 99e.

A summary of the population data computed from the pellet counts is given in Table 3.

TABLE 3

Devils Garden Deer Numbers Based on Pellet Counts

Winter	Number of deer	Remarks
1946-47	12,000	Incomplete survey
1947-48	20,000	Complete—183 plots
1948-49	28,800	Complete—384 plots[1]
1949-50	23,000	Incomplete survey

[1] Statistical analysis of the 1948-49 pellet data indicates that the probabilities were 19 out of 20 that the actual average number of pellet groups per plot (based on all plots in all vegetation types) was within 22.2 ± 2.6 groups.

There are several possible sources of error involved in pellet counts. (1) Deer that die during their stay on the winter range leave after them numbers of pellets groups that vary with time spent alive on the area. This will tend to make the computed spring population too high, but may be satisfactory for the average winter population. (2) In hilly or mountainous country a source of error lies in the counting of pellet groups on surface acres, whereas compilation must, without considerable expense, be based on map acres. This will tend to make computed populations low inversely to degree of slopes. (3) On slopes, pellets may be washed away or covered with silt, which will tend to make computed populations low. (4) In rocky, brushy, or grassy country some pellet groups may be overlooked which will make the counts conservative. (5) There may be a loss of pellet groups through trampling. This source of error will increase with deer density, and will tend to make the counts too low. (6) Pellet groups of the previous year may be counted as of the current year. Unless care is taken to overcome this source of error, computed populations may be much too high. (7) The conversion factor of 12.7 groups to one deer-day may be higher or lower than the true average. (8) Unless a sufficient

number of plots are counted to secure a reliable sample, the sampling error may be large (Leopold, et al., 1950).

Considering that the topography on the Devils Garden winter deer range is mostly flat or gentle, with only a few pronounced hills and buttes, and that the cover tends to be open rather than dense, and that men were trained to distinguish pellets of different age classes, it is believed that several of these sources of error have been held to a minimum. *The data derived from the 1949 count, when 384 plots were counted, may well be the most reliable approximation to date of the true size of the combined deer herds.* It is believed that the pellet count method of determining deer populations is the most promising method used in the deer study.

Comparison of Census Data

In order to facilitate comparison, a summation of population data is presented in Table 4.

TABLE 4

Comparison of Deer Numbers Based on Different Census Methods

Season	Entire herd		Interstate herd
	Strip count	Pellet count	Track count
1946-47	12,400	12,000	10,826
1947-48	9,800	20,000	9,665
1948-49[1]	23,400	28,800	14,011
1949-50	10,200	23,000	13,256

[1] Year of deep snow and concentration of deer.

In making this comparison it should be remembered (1) that the strip counts covered a smaller area than the pellet counts for all seasons except 1946-47, (2) that populations computed from pellet counts for 1946-47 and 1949-50 are based on incomplete data, (3) that populations based on the track counts are for deer that migrate to Oregon only, (4) that the strip count population for 1949-50 was incomplete. The northwestern portion of the range could not be counted in the spring of 1950 because roads were impassable.

The count data made during 1948-49 is the most complete. The population as computed from the pellet count, which sampled a larger area than the strip count, totaled 28,800 head. When the pellet data is computed on the basis of the area covered by the strip count, a population of 24,200 head is obtained. This may be compared with the total of 23,400 head computed from the strip count. The figures are in close agreement. A total population of 28,000 head, of which at least 15,000 are interstate migrants, may be considered as a close approximation of the true number of deer in the herds that came to winter on the Devils Garden area during the winter of 1948-49.

THE COMPOSITION OF THE DEER HERD

The composition of the deer herd wintering on the Devils Garden range has been based on careful counts made during the rutting season in late November and December when bucks move freely in the open.

Since the start of the cooperative study, no groups of deer have been included in the count unless every individual in the group has been classified. This practice tends to eliminate errors caused by (1) counters concentrating attention on unusual deer, such as large bucks, while other animals are slipping away uncounted, or, conversely, (2) the missing of more wary buck deer that run off while other animals are being tallied. Counts are made with field glasses to prevent the inclusion of spike bucks in the doe column, to segregate antler classes, and to help distinguish large fawns from small yearlings. Bucks are classified by antler classes. Yearling does are not segregated from mature does.

FIGURE 100. Field glasses are used to help the observer segregate deer into bucks, does and fawns. *Photograph by U. S. Forest Service.*

A comparison of herd composition, doe : buck and doe : fawn ratios, and bucks by antler classes, for the various years of study will be found in Tables 5, 6 and 7.

TABLE 5

Herd Composition for Years of Study

Season	Number of animals classified	Percentage of herd		
		Bucks	Does	Fawns
1943-44	5,986	8.6	63.2	28.2
1944-45	3,007	8.0	55.0	37.0
1945-46	1,696	6.4	60.4	33.2
1946-47	1,603	9.0	57.0	34.0
1947-48	1,736	8.1	59.0	32.9
1948-49	297[1]	5.4	51.2	43.4
1949-50	1,835	8.1	47.4	44.5

[1] Poor sample due to stormy weather and bad road conditions.

TABLE 6

Bucks and Fawns Per 100 Does for Various Years

Season	Number of animals per 100 does		Number classified
	Bucks	Fawns	
1937-38	18	81	1,262
1938-39	29	125	2,882
1939-40	20	103	1,338
1943-44	14	45	5,986
1944-45	15	67	3,007
1945-46	11	54	1,696
1946-47	16	61	1,603
1947-48	14	56	1,736
1948-49	11	85	297
1949-50	17	94	1,835

TABLE 7

Percentage of Antler Classes in Buck Population

(Number of Points)

Season	1	2	3	4	4+
1943-44	5	30	30	28	7
1944-45	9	28	25	34	4
1945-46	8	26	26	38	2
1946-47	10	25	22	30	13
1947-48	19	40	17	18	6
1948-49[1]	25	31	19	13	12
1949-50	29	42	12	14	3

[1] The 1948-49 data are based on only 16 bucks.

It is evident from a reading of these tables (1) that the number of fawns per 100 does has risen sharply during the last two years, (2) that the buck population has fluctuated around an average 14 per hundred does during the last seven years but was higher for 1949-50, (3) that there has been a significant increase in the number of spiked deer in the herd.

It has been shown that development of antlers of white-tailed deer is affected by the quality of food on which the deer must subsist (Severinghaus, et al., 1950). Latham (1950) states that in Pennsylvania "any spike buck is an abnormality, reflecting the over-browsed condition of the range, and spikes are common only when the animals are improperly nourished." The Rocky Mountain mule deer normally may be expected to produce at least forked-horn antlers when yearlings. The marked increase in spike bucks among the deer wintering on the Devils Garden area may well be a product of poor nutrition.

Productivity and Survival

During the winter of 1945-46, 12 females were taken from the deer herd for study purposes and the following winter 59 mature females and one yearling. They were taken at monthly intervals during the winter period. It was found that pregnancy could be determined in animals taken after January 14. Of the 49 does examined after that date, all but

the yearling were pregnant. The number of embryos per pregnant doe was found to be 1.75 (Chattin, 1948).

The ratio of 175 embryos per 100 does was based on mature animals only. Ordinarily the yearling class of does will breed during their second winter. The one yearling in the sample was hardly representative of this class of breeders. However, the study did indicate that the rate of fawn conception was up close to the full potential for Rocky Mountain mule deer.

Losses of embryos from reabsorption, abortion and stillbirth occurs among animals in poor condition as a result of malnutrition and/or disease. Assuming that no such losses occurred among does in the Devils Garden deer herd, the study indicates that at least 150 live fawns were born for every 100 breeding does in the herd.

Doe:fawn ratios determined by deer counts usually are based on all does of yearling age or greater. Attempts to segregate yearling from older does while making composition counts often results in gross errors. Among Rocky Mountain mule deer, the yearling class is not expected to produce fawns. What percent of the does breed as fawns is not known, but is considered negligible. Therefore, an allowance must be made for yearlings to make the doe:fawn ratios comparable directly with the potential of 150 fawns per 100 breeding does.

Assuming, for the sake of discussion, that 15 percent of the doe herd is composed of yearlings, the doe:fawn ratio of 56 fawns per 100 does for the 1947-48 season would indicate there were 56 fawns for every 85 does of breeding age, or 66 fawns for every 100 mature does in the herd. Likewise the doe:fawn ratio of 94 fawns per 100 does for the 1949-50 season indicates there were 110 fawns for every 100 mature does in the herd that winter.

If 150 fawns per 100 does were born during each of the years in question, the loss of fawns up to the time the November-December composition counts were made was 84 for 1947 and 40 for 1949.

Factors Influencing Survival

Forage conditions on the winter range, as indicated by the condition of bitterbrush and juniper browse, have worsened during this three-year period. Browse conditions on the summer range reportedly have remained good. Only two other influences come to mind that have changed during the period. (1) Favorable precipitation has resulted in a better than normal growth of grass during the springs of 1948 and 1949. (2) A progressive reduction of predators by use of the poison 1080 had reduced the coyote population on the summer range to a very low density during the summers of 1948 and 1949. It is possible that one or both of these influences may be responsible for the recent sharp rise in fawn survival.

It is probable, however, that winter food conditions are responsible for the great loss of fawns that must occur on the range after the counts are made in early winter. It will be seen in Table 5 that fawns made up 43.4 percent of the deer herd in late 1948. Normally, the fawn crop may be expected to be made up of 50 percent males and 50 percent females. In short, about 21.7 percent of the herd was made up of male fawns. Had all of these survived, the percentage of bucks in the herd should have been much higher in late 1949 than the 8.1 percent shown in the table. Table 7 shows that spikes and 2-point bucks made up 71 percent of the

total buck herd in 1949. In other words, the yearling buck class made up only 5.8 percent of the entire herd. The difference between this figure and what should be expected had all the 1948 count of fawns survived to become yearlings indicates that heavy losses of fawns are occurring after counts are made. Fawns and old age classes of deer are the first to succumb where good forage is in short supply.

Other life history data concerning deer that winter on the Devils Garden area are given by Chattin (1948) and in the Second Progress Report of the Interstate Deer Herd Committee (1947).

WHAT THE DEER EAT

The analysis of the contents of deer stomachs offers valuable information on what deer eat and when they eat it. Starting with the winter of 1945-46, the contents of stomachs taken from deer on the winter range, and on the summer range in Oregon, have been analyzed. The findings are summarized in Table 8, and are presented graphically in Figure 101.

It will be seen from the table that herbaceous forage is present in the diet the year round, making up from 11.2 to 96.0 percent of the

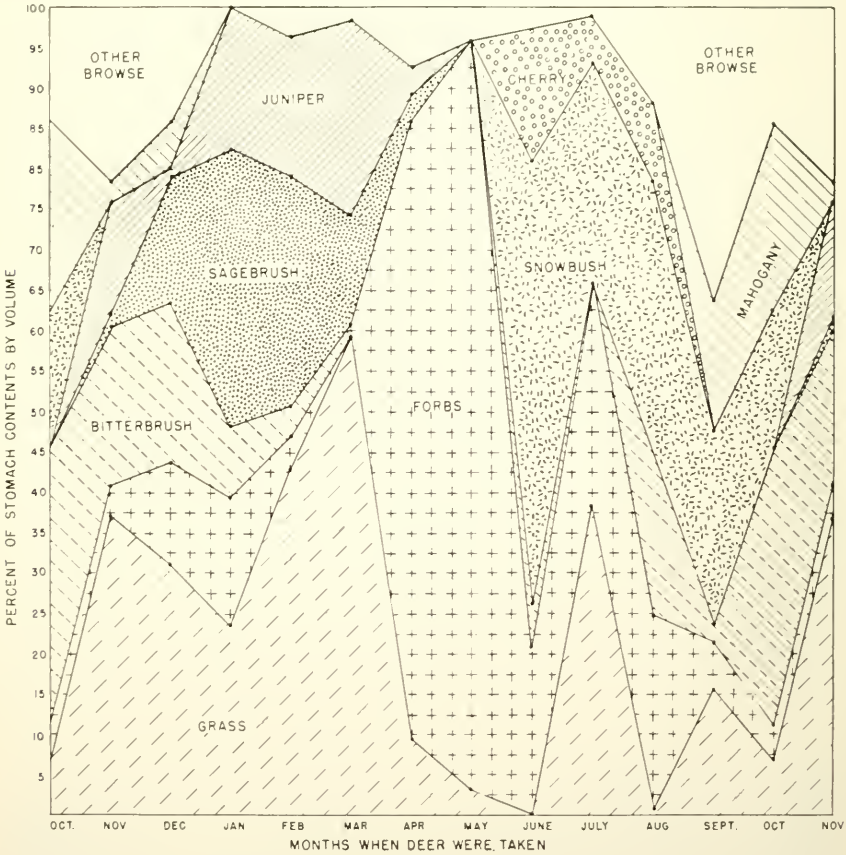

FIGURE 101. The deer diet month by month as indicated by an analysis of stomach samples

TABLE 8

Summary of Deer Stomach Contents by Percentage of Volume

Month in which deer were taken	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Number of deer in sample	16	15	15	10	5	5	5	8	6	5	50	11
Grass, green and dry	23.7	42.0	59.5	9.5	3.0	Tr.	38.2	0.9	15.8	7.2	37.3	31.6
Forbs (including fungi)	15.7	2.1	0.0	76.1	93.0	21.0	27.4	24.5	6.0	4.0	4.0	12.2
Total herbs	39.4	44.1	59.5	85.6	96.0	21.0	65.6	25.4	21.8	11.2	41.3	43.8
Purshia tridentata (bitterbrush)	8.5	7.4	1.2	0.0	0.0	5.0	Tr.	20.0	0.8	34.0	18.9	19.5
Artemesia spp. (sagebrush)	34.6	27.9	13.8	4.0	Tr.	0.0	0.0	0.0	0.0	0.0	1.4	15.9
Juniperus occidentalis (juniper)	17.5	17.4	23.4	2.9	Tr.	0.0	0.0	Tr.	0.0	Tr.	14.3	0.8
Ceanothus velutinus (snowbrush)	0.0	0.0	0.0	0.0	0.0	55.0	27.4	34.0	25.0	17.0	0.0	0.0
Prunus spp. (wild cherry)	0.0	0.0	0.0	0.0	Tr.	17.0	6.0	8.8	Tr.	0.0	0.0	0.0
Cercocarpus ledifolius (mountain mahogany)	0.0	0.0	0.0	Tr.	0.3	1.0	0.0	Tr.	15.8	23.4	2.4	5.5
Ceanothus prostratus (squaw carpet)	0.0	0.5	1.4	0.1	0.4	Tr.	0.0	1.9	1.1	11.0	19.8	8.6
Berberis sp. (Oregon grape)	0.0	Tr.	0.0	0.0	0.0	Tr.	0.0	Tr.	10.0	1.2	0.0	0.0
Other browse (including lichen)	0.0	2.7	0.7	7.4[1]	3.3	1.0	1.0	9.9[2]	22.5[3]	2.2	2.2	5.9
Total browse	60.6	55.9	40.5	14.4	4.0	79.0	34.4	74.6	78.2	88.8	58.7	56.2

[1] Other browse includes *Arctostaphylos patula*, 6.9 percent, and lichen, 0.5 percent.
[2] Other browse includes *Arctostaphylos* spp., 6.2 percent, *Amelanchier* spp., 3.1 percent, and lichen, 0.6 percent.
[3] Other browse includes *Amelanchier* sp., 2.8 percent, lichen, 8.7 percent, and others (mostly *Pachystima myrsinites*), 11.0 percent.

stomach contents, depending on the time of year. Since this class of forage is generally more easily digested than browse, it is probable that grass and forbs may play an even more important part in the deer diet than the data indicate. The fluctuating use during the summer months is more probably the result of poor sampling, rather than change in preference. Dry grass and forbs (mostly *Balsamorhiza sagittata*) are taken in the late fall and early winter. Some of this dry forage, particularly grasses, probably is taken inadvertently in attempts to nip the fresh green blades that start to grow at this time. Herbaceous vegetation may play a more vital role in deer nutrition than generally is believed at present. However, during the critical periods when snow covers the herbaceous forage on the winter range, grasses and forbs are not available to deer. For this reason grasses and weeds do not make a dependable base for the regulation of deer numbers.

Snowbrush (*Ceanothus velutinus*) appears to play an important role in the summer diet of the interstate deer herd. It appeared in deer stomachs from June to October, inclusive, and averaged 17 to 55 percent of the stomach contents. It was supplemented by wild cherry (*Prunus* spp.), mountain mahogany (*Cercocarpus ledifolius*), bitterbrush, and squaw carpet (*Ceanothus prostratus*).

Bitterbrush was used throughout the year, with the exception of April and May when grasses and weeds made up most of the deer diet. The use of bitterbrush appears to be heaviest in October, when it averaged 34 percent of the material found in the deer stomachs. The stomach samples indicate that this use falls off as the winter progresses to 1.2 percent in March and none in April.

Sagebrush appears as strictly a winter food, while juniper browse is very nearly so. As bitterbrush declines in the deer diet, the use of sagebrush and juniper increases. The reasons for this shift from bitterbrush to sagebrush are not known. Much of the bitterbrush on the midwinter concentration area is moderately to heavily cropped by January. Aldous (1945) reported that tips and bud ends of bitterbrush twigs are highest in nutrients. Nutrients fall off in cropped stems. Perhaps this, in part, may account for the shift. Sagebrush is the most abundant browse on the winter range.

Sagebrush has been reported in Utah as about half as high for digestible protein and twice as high for digestible fat and carbohydrates as is green alfalfa. Chemical analysis indicates it should be readily digestible and nutritious feed (Smith, 1950a). On the other hand, deer feeding studies in Utah indicate that deer soon reach satiation in the consumption of sagebrush and turn to other forage species unless forced by lack of other forage to subsist wholly upon it (Smith, 1950b). It was found on the Lassen-Washoe interstate winter deer range in Nevada and California that deer have died as a result of malnutrition (as indicated by bone marrow) on ranges where sagebrush in all age-classes was abundant. The sagebrush present on the Lassen-Washoe range is predominantly big sage (*A. tridentata*). On the Devils Garden range, black sage (*A. arbuscula*) is also present in abundance.

During the winter of 1950-51, a collection of browse materials will be clipped at monthly intervals so that chemical analysis for nutrients can be made. Perhaps the findings will throw light on the reason why deer

change from bitterbrush to sagebrush in midwinter on the Devils Garden range.

It is recognized that the examination of the contents of deer stomachs will not always reveal true food preferences or exact diets. The stomach contents from deer on depleted ranges will disclose the forages of necessity rather than preference. Differential digestion and assimilation are factors which must be considered also. Succulent materials pass through the stomach rapidly; dry, woody materials digest slowly (Norris, 1943). Nevertheless, the analysis of contents of deer stomachs does yield knowledge of the feeding habits of these animals and provides data on which to base management.

THE DEER RANGE

Systematic studies of forage utilization by deer were started by Modoc national forest personnel during the winter of 1943-44. Twenty line transects were established at mechanical intervals in bitterbrush types. Plots were laid out in various lengths so as to sample 20 bitterbrush shrubs at each location.

Livestock are removed from the Devils Garden area at the time the first migrant deer arrive in the fall. Conversely, deer start to move toward their summer ranges before livestock are permitted on the area in the spring. As a result, it is a simple matter to separate livestock cropping from cropping by deer.

The 20 plots were checked in the late fall to obtain percentage cropping of bitterbrush by livestock, and in the spring to obtain total utilization. The difference was assigned to deer.

The findings indicated that average cropping of the seasonal leader growth of bitterbrush was 64.7 percent. It was reported that livestock took 28.6 and deer 36.1 percent.

Hormay (1943) found that 60 percent utilization of leader growth was the most a bitterbrush shrub can withstand without reduction of vigor and seed production. An over-all average does not reveal what is happening to individual shrubs. In some cases, light utilization in one area may outbalance destructive use in another. The data must be broken down further in order to reveal variations in use. This was partially done for the bitterbrush study. It was reported that 58 percent of the shrubs were overutilized (Fischer et al., 1944).

After the interstate deer herd committee was organized, the Oregon Game Commission set out a new series of 19 plots in the fall of 1945, located as shown in Figure 102. Most of the plots were placed farther north than those used in the earlier study. The utilization checks revealed that total use of bitterbrush averaged 80 percent. It was indicated that livestock took 45.6 percent of the leader growth, and deer 34.4 percent (Interstate Deer Herd Committee, 1946).

A third series of 20 forage plots was established the following fall, 1946, by the California Division of Fish and Game. With some exceptions, these plots were located in the same area as the first study. Both the second and third series were checked for utilization during the winter of 1946-47. The findings were as follows:

The second series yielded an average use of 74 percent, with livestock taking 49 and deer 25 percent.

The third series yielded an average use of 73 percent, with livestock taking 40 and deer 33 percent.

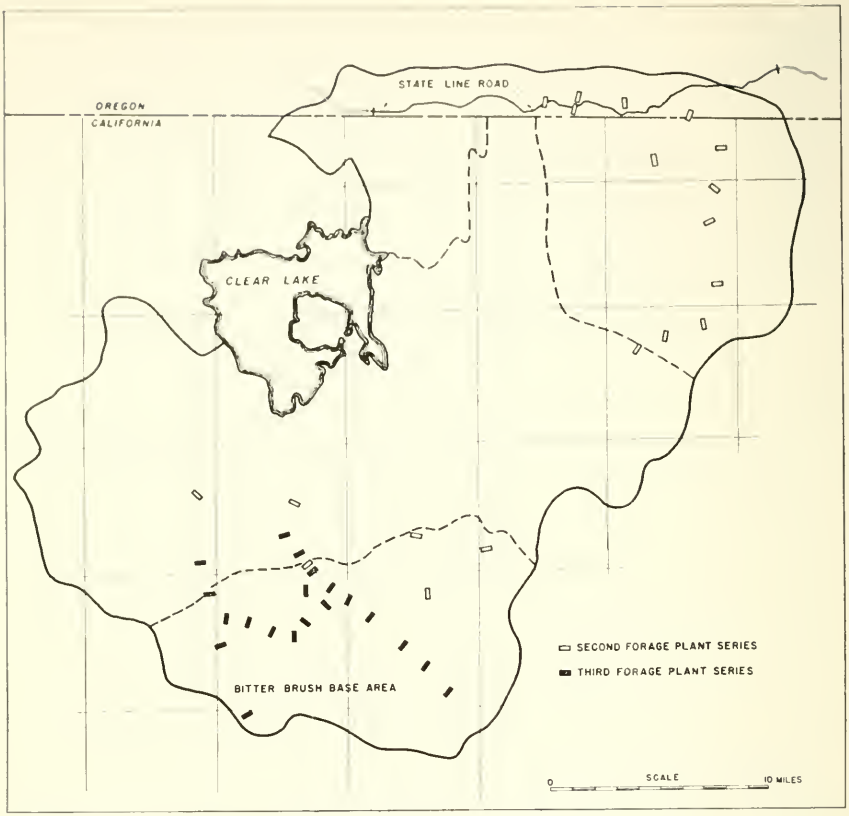

FIGURE 102. Location of forage plots established during the winters of 1945-46 and 1946-47

The data indicated that 50 out of every 100 shrubs sampled were browsed 60 percent or greater when livestock left the range in the fall. By the time deer left in the spring, 81 out of every 100 shrubs were overbrowsed. It was reported that the sample was hardly intensive enough to be used as a base for management, but it was sufficient to show the need for a reduction in animals using the winter range (Interstate Deer Herd Committee, 1947).

In addition to the utilization study of bitterbrush, a grass utilization check was made in the spring of 1947. Fifty transects were used. Each consisted of 10 square-foot quadrats located at chain intervals, along transect lines. Estimates were made to the nearest 10 percent of the amount, by weight, of the green growth cropped by deer. The findings indicated that 32 percent of the grass plants in the sample had been cropped. From these, deer had taken an average of 17 percent of the green leafage as it appeared at the time of sampling. Average utilization for all grass plants was given as 5 percent (Interstate Deer Herd Committee, 1947).

The findings of the three independent studies became a subject of considerable discussion at Interstate Deer Herd Committee meetings. It was admitted that variation in use of bitterbrush was great on the Devils

Garden area. A small number of plots was not adequate to sample this use. Findings might vary according to the areas in which plots were located. It was decided to make a fresh start in deer-livestock forage utilization studies. It was agreed that future studies would be cooperative efforts, rather than done independently by separate agencies. As a result of these discussions a plan for management of the Devils Garden winter deer range was developed and adopted by the agencies.

Interstate Winter Deer Range Management Plan

The management plan recognized that livestock production is an important industry in Modoc County. It also recognized that the deer which winter on the Devils Garden area are an important asset to the peoples of both California and Oregon, and that the number of deer that can be maintained on a thousand square miles of summer range in both Oregon and California is largely dependent on the quantity of forage available upon the 200 square miles where the deer concentrate during the critical months of February and March. Taking all values into consideration, it was agreed (1) that allowable crops of key forage species on the winter range would be divided between deer and livestock on a 50/50

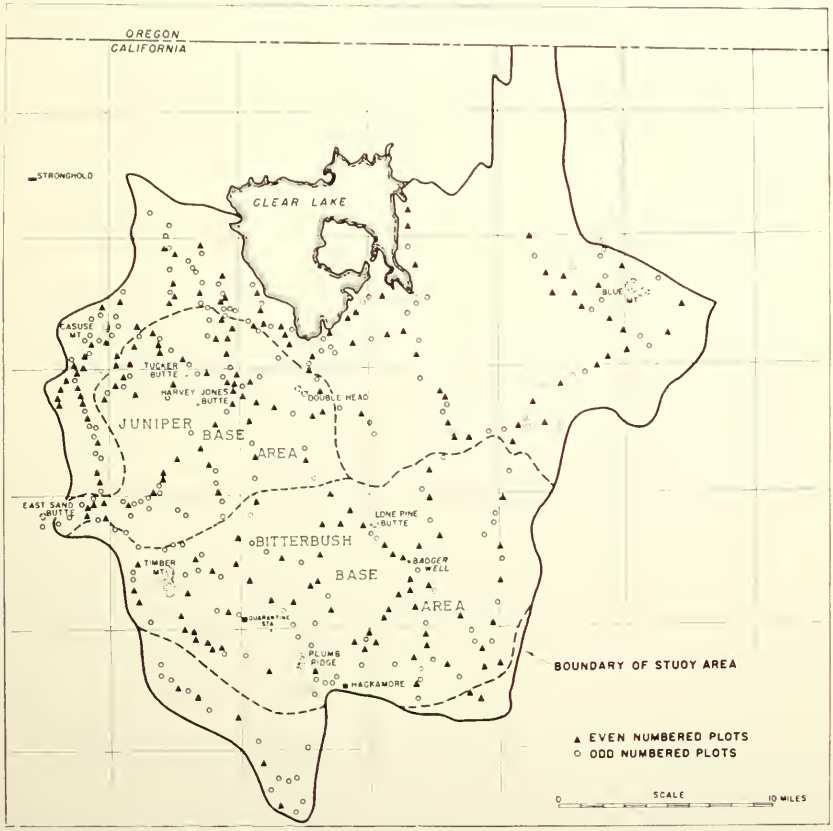

FIGURE 103. Location of new forage and pellet count plots on the winter deer range

basis, (2) that utilization data based on a system of forage plots established on the winter range would be accepted by all the agencies as a true index of forage use, (3) that adjustments in numbers of livestock and/or deer would be based on need and made on the basis of three-year running averages of forage utilization. It was agreed to apply the best principles of livestock and deer management to the area . . . in order to balance the combined use of livestock and deer with average forage production of the range . . . so that the trend in forage depletion would be reversed and range conditions maintained or improved for the future (Interstate Deer Herd Committee, 1949a).

The New Forage Plots

The California Forest and Range Experiment Station was called on for assistance in sampling the range vegetation. It was planned to use 400 plots, 100 in each of the four main range vegetation types that occur on the winter range. The plots were designed to furnish information not only on current forage utilization, but also to give data on ground coverage and vegetation composition which may be used as a base from which to measure future changes.

Two hundred plots were established in the fall of 1947, and the balance was located the following summer. A full description of the method will be found in the third progress report (Interstate Deer Herd Committee, 1949b). Briefly, each plot consists of a 200-foot line along which 20 segments, each 25 inches long, were measured by the line-interception method (Canfield, 1939 and Hormay, 1949). Plots were located at predetermined intervals along the roads, truck trails, and ways that reach into most areas on the winter range. The locations of the plots are shown in Figure 103.

Condition of the Ground Cover

A full analysis of the ground cover and percentage composition of the vegetation, as indicated by the forage plots, will be found in the fourth progress report (Interstate Deer Herd Committee, 1950). A breakdown of the principal elements will be found in Table 9.

The table shows that the percentage of the ground covered with vegetation available for deer or livestock is

28.4 in the pine-bitterbrush type
37.0 in the sagebrush type
31.7 in the juniper type
37.4 in the grassland type

In addition to this cover, an overstory of juniper trees occurs in the juniper vegetation type and an overstory of coniferous trees and some stands of unavailable mountain mahogany and wild cherry occur in the pine-bitterbrush type.

Of the available browse species present, sagebrush is most common and abundant. Sagebrush makes up

3.9 percent of available vegetation in pine-bitterbrush type
56.1 percent of available vegetation in sagebrush type
31.6 percent of available vegetation in juniper type
4.9 percent of available vegetation in grassland type

TABLE 9

Principal Elements of Vegetation on Winter Deer Range

(Based on 396 Forage Plots: 198,000 Inches of Line Intercepts)

Species	Frequency of occurrence, plots	Percentage of total vegetation coverage			
		Pine-bitterbrush[1]	Sagebrush type	Juniper type[1]	Grassland type
Annual grasses	290	4.88	4.65	15.06	33.74
Annual forbs	349	5.31	7.31	13.36	32.18
Total annuals		10.19	11.96	28.42	65.92
Perennial grasses		39.31	18.82	26.09	19.58
Perennial forbs		12.44	5.89	2.30	4.51
Total herbaceous		61.94	36.67	56.81	90.01
Bitterbrush	113	14.42	3.23	3.60	0.10
Sagebrush	217	3.89	56.11	31.59	4.95
Juniper[1]	37	1.17	0.11	2.45	0.00
Cherry (bitter and choke)	6	0.49	0.00	0.13	0.00
Mountain mahogany	8	0.88	0.00	0.16	0.00
Rabbitbrush	119	3.05	3.18	4.45	4.81
Squaw carpet	41	11.32	0.06	0.00	0.00
Other browse[1]		2.84	0.64	0.81	0.13
Total browse		38.06	63.33	43.19	9.99
Total vegetation	396	100.00	100.00	100.00	100.00
Total percentage of ground covered with vegetation		28.4	37.0	31.7	37.4

[1] An overstory of juniper occurs in the juniper type and an overstory of trees occurs in the pine-bitterbrush type.

Bitterbrush is the next most abundant browse on the winter range. Of the available living vegetation, bitterbrush makes up

14.4 percent in the pine-bitterbrush type
3.2 percent in the sagebrush type
3.6 percent in the juniper type
0.1 percent in the grassland type

The survey also measured the coverage of dead browses that were still in place on the winter range. Of the total stand of bitterbrush (dead and alive) it was found that

41 percent was dead in the pine-bitterbrush type
33 percent was dead in the sagebrush type
48 percent was dead in the juniper type

The amount of bitterbrush that occurs as scattered shrubs in the grassland type is negligible.

Form Classes of Key Browses

When shrubs and trees are not browsed, or only lightly browsed, they tend to assume the natural shapes which are normal for each species. As intensity of browsing increases, the departure from these normal forms becomes more striking. Continued heavy browsing, year after year, results in tightly hedged or high-lined and partly dead browse

FIGURE 104. A bitterbrush shrub tightly hedged by overbrowsing

plants that stand out as evidence of poor range condition and declining forage yield (Dasmann, 1951).

A classification of the forms of bitterbrush shrubs and juniper trees on 133 plots on the key area was made in 1950. Degree of hedging was broken down into (1) little or no hedging, (2) moderately hedged, and (3) heavily hedged. Availability of forage was classed as (1) all available, (2) largely available, (3) mostly unavailable, and (4) unavailable.

It was found that 30.7 percent of the bitterbrush shrubs and 33.9 percent of the available juniper trees were heavily hedged. The full findings are given in Table 10.

TABLE 10

Form Classes of Bitterbrush and Juniper

	Percentage of stand in each class	
	Bitterbrush	Juniper
1. All available, little or no hedging	11.7	16.5
2. All available, moderately hedged	53.9	30.4
3. All available, heavily hedged	30.3	19.9
4. Partly available, little or no hedging	.6	1.7
5. Partly available, moderately hedged	2.8	15.7
6. Partly available, heavily hedged	.4	14.0
7. Mostly unavailable	.0	.9
8. Unavailable[1]	.3	.9
	100.0	100.0

[1] Includes only living plants.

Age Classes of Key Browses

The absence, or scarcity, of one or more age classes from a stand of vegetation gives cause for deliberation. This is especially so when younger age classes are scarce even though older stands are dying out. Unless there has been a recent change in such site conditions as climate and soil, the absence of younger age classes from a stand will often indicate overcropping by range animals. The younger age groups of preferred browse species are particularly susceptible to losses resulting from overcropping.

To determine the age-factor of the stand of bitterbrush and juniper on the winter range, these browses were classified as either seedlings, young plants, mature plants, or decadent plants. It was found that

1.0 percent of the bitterbrush sampled was seedlings
15.4 percent of the bitterbrush sampled was young plants
55.6 percent of the bitterbrush sampled was mature plants
28.0 percent of the bitterbrush sampled was decadent plants

The balance between age classes of juniper trees was more even, as is shown in Table 11.

TABLE 11

Age Classes of Bitterbrush and Juniper

	Percentage of stand in each class	
	Bitterbrush	Juniper
Seedlings	1.0	1.7
Young plants	15.4	68.7
Mature plants	55.6	27.9
Decadent plants	28.0	1.7
	100.0	100.0

The fact that 30 percent of the bitterbrush stand was revealed as heavily hedged, and that nearly twice as many shrubs are in the decadent class as are in the seedling and young plant categories, indicates that forage depletion is still in progress on the Devils Garden area.

Forage Utilization

The grasses, forbs, and browses on forage plots are checked for utilization each fall and spring by work teams composed of representatives of all the agencies. Utilization of grasses is estimated by the height-weight method (Lommasson and Jensen, 1942). Percentage cropping of browses is estimated by the method described by Hormay (1943), except that juniper twig utilization is actually measured on tagged twigs. Use of forbs is estimated on a percentage-volume basis.

Utilization data on all plants except annuals were taken during the first two years of the study (1947-48 and 1948-49). It was found that grasses were commonly cropped by deer, and rather heavily on limited spots, but that average utilization was light. The blue grasses (*Poa secunda* and *nevadensis*) appeared to be most relished and were most heavily used (4.5 percent in 1947-48). Needle grasses (*Stipa columbiana*

FIGURE 105. Evolution of a deer browse line on juniper trees
U. S. Forest Service photos

and *elmeri*) were next in degree of use with an average cropping of 2.9 percent of the green leafage in 1947-48.

Arrowleaf balsamroot (*Balsamorhiza sagittata*) appeared as the most heavily cropped forb that covered more than 0.1 percent of the ground surface of the winter range. But by fall the cropping of balsamroot only averaged 3 percent. Time-consuming utilization checks on grasses and forbs were discontinued after 1948-49.

Among the browses, bitterbrush appeared as by far the most heavily cropped shrub, with juniper second in degree of use. Sagebrush fell fourth, the cropping of rabbitbrush being somewhat heavier. Because cropping of bitterbrush and juniper was much greater than the use of other forage species on the range, it appeared obvious that if animal numbers were kept at levels at which these browses received no more than proper use, no other forage species would generally be overutilized. For this reason, bitterbrush and juniper were chosen as key forage species. Starting in 1949-50, utilization checks have been confined to key species on key areas, except that other browses are checked where they occur on plots on which key species are present.

One rough index of the relative importance of various forage species in the diet of deer can be compiled by multiplying the amount present on the range by the amount that was eaten, in other words, percentage of the ground covered by the species by average percentage cropping. This was done with bitterbrush, sagebrush and rabbitbrush as they occur on the deer concentration area. The index of their relative importance in the deer diet during the 1949-50 winter season was computed as

74 for bitterbrush
65 for sagebrush
20 for rabbitbrush

An index for juniper could not be computed because, as yet, no good figure on relative ground covered by all classes of available juniper browse has been determined.

Evaluation of Range Survey Procedures

The principal sources of error that may influence both forage inventories and forage utilization checks are (1) unrepresentative or biased sample plots and (2) biased, or inaccurate measurements or estimations by range examiners. Steps were taken to reduce these sources of error.

Although the sample plots were set out at predetermined mechanical intervals along established base lines, and are not strictly randomized, it is believed they do yield a representative sample. The topography of the area tends to be gentle; hence the roads and ways are not mostly located on ridge-tops or valley bottoms as is apt to be the case where topography is more pronounced. Initial points of the line transects were set 50 feet from the roads so as to eliminate the immediate influence of the passageways. Plots were run at right angles to the road at point of departure so as to reduce the bias of selection.

As for the range examiners, the men that assemble each season to check the plots train together before the actual work starts in order to standardize measurement and estimation procedures and to level off individual bias. While a certain amount of error due to all sources does exist, it is believed that it is not great. Statistical analysis of the data on total

bitterbrush cropping for the 1949-50 season indicates the probabilities are 19 out of 20 that the true average lies within 11.7 percent of the computed average.

BITTERBRUSH BASE AREA

Both the range vegetation survey and general observations reveal that there are extensive acreages of winter range on which bitterbrush is scarce. Cropping of bitterbrush is generally much heavier where it occurs as scattered plants. To reduce stocking to a level where these sparse stands would be properly used is not practical. It was decided to sacrifice bitterbrush on areas where this species naturally was scarce or where it was heavily depleted. It was planned to base reductions in numbers of deer or livestock on utilization of bitterbrush, the key forage species, only where it occurred in sufficient abundance to make management practical. The area of which this is true is called the *bitterbrush base area*. Elsewhere, juniper is regarded as the key forage species for deer. This is called the *juniper base area*. The location of these areas is shown in Figure 103.

Three-Year Utilization of Key Forage Species

As was stated above, the agencies concerned with managing the Devils Garden deer herd and its range, agreed that adjustments in levels of stocking would be based on utilization of key forage species over three-year periods. The reason for the use of three-year averages is that the management plan seeks to base stocking on trends in range condition rather than on the effect of exceptionally good or bad growth years.

Bitterbrush

The first three-year period began with the season of 1947-48 and ended with that of 1949-50. During these three seasons the cropping of bitterbrush on the bitterbrush base area by livestock has gradually lightened, while the use by deer has become heavier. This is shown in Table 12. The percentage of the stand which is subject to overbrowsing also has increased during the three-year period. It has gone up from 30 percent in 1947-48 to 40 percent in 1949-50. This is shown in Table 13.

TABLE 12

Average Cropping of Bitterbrush for Three Years[1]

Class of animals	Average percentage cropping			
	1947-48	1948-49	1949-50	3-year average
Livestock	20.1	18.4	13.4	17.3
Deer	16.2	21.5	27.5	21.7
Total	36.3	39.9	40.9	39.0

[1] A sizable fraction of the bitterbrush plots used in early studies were located in areas on which bitterbrush is now sacrificed. Most of the other plots were located in areas where use of bitterbrush is also normally heavy. For this reason the utilization averages derived from early studies are much higher than the averages based on plots scattered over the entire bitterbrush base area.

TABLE 13

Percentage of Plots on Which Bitterbrush Cropping Was 60 Percent or Heavier

Season	Fall	Spring
1947-48	10	30
1948-49	13	34
1949-50	12	40

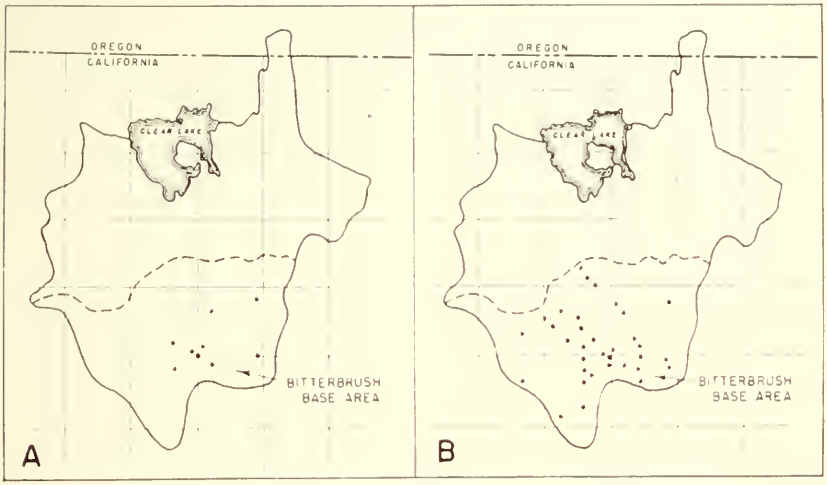

FIGURE 106. Location of bitterbrush plots on which cropping averaged 60 percent or greater (a) after livestock left the range in the fall and (b) after deer left the following spring (1949-50)

An analysis of the ground cover data on bitterbrush indicated that 8 percent of the stand of living bitterbrush present on the bitterbrush base area when the surveys were made had died since the plots were measured in 1947 and 1948. This is far in excess of the present rate of natural reproduction, and is at least partially a result of overbrowsing.

Since the areas on which it is thought practical to sacrifice bitterbrush have been excluded from the bitterbrush base area, the sizable percentage of the stand subjected to damaging use is of considerable significance. While a certain amount of overcropping is usually unavoidable on even the best managed ranges, it is believed that when such a large and increasing percentage of the stand is subjected to overcropping there is need for immediate reduction in the number of animals using the winter range.

Juniper

Cropping of juniper fluctuated during the three-year period. The percentage of available growth cropped by deer averaged

14.0 percent in 1947-48
22.2 percent in 1948-49
12.3 percent in 1949-50

Utilization was heaviest during the severe winter of 1948-49. This was to be expected, since juniper is to some extent an emergency food which is taken by deer more during periods of bad weather when they are bunched in cover. Use of juniper by livestock is negligible.

The tolerance of juniper to browsing has not been determined by published studies. Aldous (1941) found that northern white cedar (*Thuja occidentalis*) could not maintain growth of browse if more than 25 percent of its foliage was removed annually. Juniper is a more open-growing tree than northern white cedar, and its capacity to regenerate growth on lower branches may be somewhat higher, although it is very slow.

The studies revealed that the percentage of the plots on which the average use of juniper was higher than 25 percent was as follows for the different years:

1947-48	17 percent
1948-49	29 percent
1949-50	11 percent

Sagebrush and Rabbitbrush

Cropping of sagebrush averaged 9.1 percent on the plots examined during 1949-50. Livestock took 0.2 and deer 8.7 percent of the leafy growth. Rabbitbrush cropping averaged 13.9 percent, of which livestock took 2.8, rodents 2.4, and deer 8.3 percent during the 1949-50 season.

REDUCTION PROGRAM

The range studies consistently have indicated the need for a reduction in stocking by deer and livestock on the Devils Garden area, if the demand for food is to be balanced against the supply of allowable forage. In order to halt range depletion, and insure a continuing supply of good range forage for the future, steps have been taken to reduce livestock use of the area and to increase the hunter harvest of deer.

Reduction of Livestock

Cattle and Sheep

During the three-year period terminating with the season of 1949-50, the use of the Devils Garden winter deer range by livestock has been reduced. This is reflected in the decreasing amount of bitterbrush cropping by livestock.

The number of livestock that graze on national forests can be expressed in three ways, i.e., obligations, permitted use, and actual use. Stockmen (1) who were using the public lands prior to the creation of the national forests, (2) who had established ranch headquarters, (3) who possessed sufficient outside range to feed their stock without damage to the resource during periods when stock was not permitted on the national forest lands, and (4) who were United States citizens were granted the preference of receiving grazing privileges on national forest lands. During subsequent years, preferences have been granted to homesteaders and others who met certain requirements. These grazing privileges are considered as obligations by the Forest Service.

National forest permittees who hold grazing preferences often, for various reasons, do not apply to graze full numbers each year. Hence the number *permitted* during any one year may vary considerably from the

number *obligated*. After receiving his permit, a permittee may decide to graze fewer animals or to graze for a lesser period than the permit specifies. Hence *actual use* may be different from *permitted use*. Also number of livestock allowed on the forest on a temporary year-to-year basis, and livestock permitted because of privately owned lands, serves to confuse the question of livestock numbers. For instance, the livestock data given in the published management plan (Interstate Deer Herd Committee, 1949a) is based on actual use. This will differ from the data found in Table 14, which is based on obligations. It is believed that the number of livestock covered by obligations makes the logical base on which to compute increases and decreases of livestock on the winter deer range.

The obligations for the winter range for 1946 and 1950 are given as follows:

1946 ..... 20,542 animal unit months[1]
1950 ..... 17,404 animal unit months

This represents a 15.3 percent reduction in livestock grazing obligations.

TABLE 14

Livestock Obligations on the Devils Garden Winter Deer Range

Allotment	Percent within winter range	1946		1950	
		Head[1]	Animal unit months	Head[1]	Animal unit months
Casuse	100.0	1,250 S	500	1,250 S	500
Clear Lake Spring	100.0	12,750 S 630 C	6,993	11,350 S 530 C	4438
Hackamore	47.6	595 S	476	524 S	419
Hog Lake	27.4	247 S	197	329 S	110
Lava Bed Winter	14.9	745 S	373	745 S	373
North Badger	100.0	1,125 S	900	1,000 S	800
South Badger	100.0	1,250 S	1,000	900 S	720
Boles Meadow	46.6	1,398 C	4,753	1,277 C	4,889
Dry Lake	82.4	190 C	1,051	231 C	1,302
Howard Gulch	11.7	90 C	406	55 C	266
Mowitz	100.0	350 C	1,750	300 C	1,500
Potter Pasture	100.0	470 C	1,880	470 C 578 S	1,880
Timber Mountain	46.2	53 C	263	7 C	207
		17,962 S 3,181 C	20,542	16,676 S 2,870 C	17,404

[1] C: Cattle, S: Sheep.

Wild Horses

A wild horse problem has been present on the winter range for years. Attempts are made to keep down the wild horse population by periodic removals. By 1946, wild horses had again built up to numbers that made considerable use of the range forage. During April and May, 1946, under an order issued by the Secretary of Agriculture, 287 horses were removed from the range. These horses had used the range yearlong, consuming over 3,400 horse-months of forage each year. The removal of these animals has reduced the pressure for forage on the winter range and has resulted

[1] An animal unit month is a measure of livestock range use. It means that one mature cow with her calf has grazed for one month. Sheep use is converted to animal unit months at the ratio of five sheep to one cow.

in increasing the supply of food for other classes of range animals (Interstate Deer Herd Committee, 1947).

Deer

During the winter of 1947-48, an attempt was made to remove some of the surplus deer by trapping and transplanting. Montana corral type traps were used. All traps had catch pens and loading chutes attached. Trapped deer were transported in pickup trucks to a large barn where they were held until enough accumulated to make a two-ton truckload.

Success in the trapping venture was hampered by difficulties in obtaining materials for construction of traps.

During the period between January 7 and April 10, 72 deer were trapped. Of this number 49 were transplanted to other areas, nine died, and 14 escaped. This resulted in the removal of 58 deer from the winter range (Interstate Deer Herd Committee, 1949b).

Current Reduction Program

Application of the three-year reduction formula, based on bitterbrush utilization, indicated that a further reduction in livestock and a considerable increase in the deer harvest was needed to bring the level of stocking into closer balance with forage production on the winter range.

It was decided that since the level of range use which prevailed during 1947-48 resulted in overbrowsing of 30 percent of the bitterbrush stand, the amount of cropping that should be considered allowable obviously should be less than that of 1947-48. On the other hand, it was believed advisable to make gradual reductions on an experimental basis rather than to make drastic cuts. With this in mind, it was decided to accept 34 percent cropping as the average use of bitterbrush that would be allowed on the winter range.

The three-year formula was applied as follows:

	Livestock	*Deer*
Three-year average cropping	17.3	21.7
Allowable average (50/50)	17.0	17.0
Overuse	0.3	4.7
Percentage reduction of animals needed	2	20

It was planned to make the 2 percent reduction in livestock use on the deer winter concentration area where it is most needed. A reduction of 108 animal unit months is indicated.

Again, because of the experimental nature of antlerless deer hunts in California, it was decided to apply the 20 percent reduction figure to a number of deer equal to the Oregon migrants, or 15,000 head, and leave the balance of the deer on the range to serve as a safety factor. This resulted in a planned reduction of 3,000 antlerless deer. Accordingly, special antlerless deer hunting seasons were opened in Oregon, on October 18-19, 1950, and in California, from November 4 to 12, inclusive, in order to allow the removal of 1,500 antlerless deer in each state.

THE ANTLERLESS DEER HUNT

Considerable opposition developed in California against the Devils Garden antlerless deer season. California has had a buck law since 1883. Only two other antlerless deer seasons, one on Santa Catalina Island during 1949-50 and one on the Mineral King federal game refuge in 1950,

have been held in this State. As a result many people are unaware of the need, and the value, of harvesting surplus deer whether male or female.

Were it not for the active support of the local organizations of sportsmen and stockmen, as well as state-wide organizations, who are represented in the Interstate Deer Herd Committee and/or were aware of the facts in the case, it is probable the hunt would have been cancelled. In general, the persons best informed have been in support of managing the deer herd that uses the Devils Garden winter deer range. They realize that unless a deer herd is kept in balance with the supply of good forage on its range, wasteful losses occur.

As it turned out the antlerless deer hunts were quite successful. No hunting accidents occurred and there was little law violation. The participants represented a cross-section of the hunting public. Many of the participants were interested in learning facts about deer management. The majority of the hunters were well satisfied with the special season. However, in spite of this there has been considerable adverse publicity in California from individuals and groups that oppose the hunting of female deer.

A breakdown of the resultant antlerless deer bag reveals that

688 animals were taken in Oregon
1,319 animals were taken in California.

The special hunts resulted in the removal of a total of 2,007 antlerless deer, or about two-thirds of the planned objective. In Oregon 53 out of every 100 hunters permitted to hunt bagged a deer. The success ratio on the winter range in California was slightly over 94 out of every 100 hunters.

Of the total animals checked, the age classes were as follows:

Mature does	68.9 percent
Yearlings	13.6 percent
Fawns	17.5 percent
	100.0 percent

The average dressed weights of mature does taken in California was 90 pounds, of yearlings 70 pounds, and of fawns 41 pounds. In Oregon weights were somewhat higher, older does averaging 97 pounds, young does 76 pounds, female fawns 42 pounds, and male fawns 47 pounds. The average dressed weights of Rocky Mountain mule deer taken from an area of good range in northern Utah was 101 pounds for does and 55 pounds for fawns (Stoddart & Rasmussen, 1945).

PRODUCTIVITY AND HARVEST

With a herd of approximately 28,000 deer a harvest of 2,007 antlerless animals, plus an estimated regular buck kill of 2,500 animals (500 in California and 2,000 in Oregon) represents a total take of 16.1 percent of the early winter population. Tested deer management practice in other western states indicates it is possible to harvest each year a number of deer equal to 20 to 30 percent of the winter population without lowering the level of production. Obviously, the action taken on the ranges of the Devils Garden deer herd should not be expected to result in an overall reduction in deer numbers nor can it be expected to bring the herd into balance with the forage supply on the winter range.

During the last three years (1947-48, 1948-49, 1949-50) the number of fawns in the herd has averaged 40.2 percent of the total population, or approximately 11,200 animals. In short, the herd of 28,000 deer may be expected to produce an average of 11,200 fawns per season, or a net production until late fall of 40 percent if favorable survival conditions prevail.

Allowing a generous 33 percent of the production for replacement of all normal natural losses, a surplus of 7,500 animals remains each season available for harvest by sportsmen. Of these, sportsmen ordinarily bag about 2,500 bucks. Obviously, if the remaining surplus of 5,000 animals was to survive each year, the deer population would rapidly grow to great magnitude. But these surplus animals do not survive. Because the present deer population already out-balances the range carrying capacity, this surplus is lost each year from winter kill or other causes.

FIGURE 107. Because deer numbers exceed the carrying capacity of the winter range, surplus deer are lost each year from winter kill or other causes

No systematic study has been made to date of the number of deer that die each year on the winter range. The apparent low survival of buck fawns to yearling age, indicates a high mortality. General observations indicate there has been a considerable loss during the winters of 1948-49 and 1949-50. The Interstate Deer Herd Committee plans to make such a study during the winter of 1950-51. Perhaps this study will reveal the magnitude of the yearly losses of deer that could just as well go into the hunter's bag if regular either-sex hunting was permitted on this deer range.

In the meanwhile, it should be pointed out that the antlerless deer hunts held in 1950 should not result in any lasting reduction of deer on the Devils Garden interstate winter deer range. It will be necessary to hold other antlerless hunts regularly during the coming years to manage

this deer herd on the sound, practical basis needed to maintain the forage resource and to provide sustained production of deer for hunters in the future.

RANGE IMPROVEMENTS

When deer become too numerous for the supply of forage on their range, there are two ways to bring supply and demand into balance. One is to reduce the demand by harvesting more deer. The other is to increase the supply by artificial range improvement.

For the Devils Garden, generally it may be said that the area is supporting as much of a cover of vegetation as present soil and moisture conditions will allow. The practical objective in range improvement on this area is not to increase the total cover, but to bring about changes in the kinds and condition of vegetation now present on the range.

The California Forest and Range Experimental Station is carrying on experiments in bitterbrush planting on the deer range. So far, these trials have not been too successful. One problem in planting palatable forages on a heavily populated deer range is the protection of the young plants until they become established. Since these young plants are succulent and palatable, they are apt to be severely damaged and killed out in a short while where good forage is in short supply. On the other hand, if the browsing pressure is reduced to a level where such plantings will survive, natural reproduction may reseed more widely and successfully than can artificial planting if there remains sufficient native seed stock on the range.

There are extensive stands of sagebrush on the Devils Garden range. Some of these occur on good soils that will respond to grass reseeding. The Modoc National Forest is clearing sagebrush from such sites and

FIGURE 108. Mountain mahogany is universally high-lined by deer browsing on the winter range

planting good perennial grasses as rapidly as funds and manpower will permit. To date, 1,680 acres of sagebrush land have been converted to grass on the Devils Garden area.

The Forest Service is also developing the supply of water on the Devils Garden range, principally by the construction of dams to hold spring run-off. Water usually is not a problem to deer during the winter period. But the scattering of waters over the range brings about better distribution of livestock during the summer months, spreading use more evenly over the area and decreasing localized range damage.

There exists a considerable acreage of mountain mahogany (*Cercocarpus ledifolius*) on the Devils Garden range. The seasonal growth of this plant species is considered an excellent deer food. But the mahogany stand consists mostly of tall, mature shrubs, or trees. These are universally high-lined from overbrowsing and offer little available forage to deer at the present time. The California Division of Fish and Game has been experimenting with coppicing of mountain mahogany by cutting the tops to determine if sprout growth can be induced. It has been found that the cut-back shrubs will produce considerable forage.

To coppice sufficient numbers of shrubs to have a material effect on the food supply would run to considerable expense. However, further efforts along similar lines are contemplated.

The construction by the Modoc National Forest of a division fence along the north boundary of the deer midwinter concentration area to hold back the spring drift of cattle already has had a beneficial effect on both the grass and browse condition of this part of the winter range. When this fence is completed, it is planned to defer livestock use of the area so as to allow native grasses to mature and bring about faster natural reseeding of perennials on the badly depleted area.

It is now the practice to reseed to palatable grasses all wild-fire burns that occur on the winter range. While this practice will hardly compensate for the critical loss of good browses that results from fire, it does result in the establishment of perennial grass stands that offer food to both livestock and deer. In 1950, 3,580 acres of wild-fire burns were reseeded to grasses by the Forest Service.

CONCLUSION

The objective in deer management is the production on each management unit of the maximum number of harvestable animals that may be carried on a sustained yield basis without serious conflict with other legitimate land uses. The Interstate Deer Herd Committee seeks to realize this objective through common sense management of the deer that winter on the Devils Garden winter deer range. Because deer numbers are in excess of the natural food supply, each year there occurs a surplus of both male and female deer on the deer range. The objective in the action policies recommended by the committee is to increase the harvest of deer on this range so that the deer herd will be brought into balance with the productive capacity of the winter range and so that surplus animals will be used rather than lost.

REFERENCES

Aldous, C. M.
1945. A winter study of mule deer in Nevada. Journ. Wildl. Mgmt., vol. 9, no. 2, p. 145-151.

Aldous, Shaler E.
1941. Deer management suggestions for northern white cedar types. Journ. Wildl. Mgmt., vol. 5, no. 1, p. 90-94.

Allman, Richard T., and T. S. Hamilton
1949. Nutritional deficiencies in livestock. F. A. O. Agric. Studies no. 3. Excerpt *In* Journ. Range Mgmt., vol. 4, no. 1, p. 41.

Canfield, R. H.
1939. Application of the line interception method in sampling range vegetation. Journ. Forestry, vol. 39, p. 388-394.

Chattin, John E.
1948. Breeding season and productivity in the interstate deer herd. Calif. Fish and Game, vol. 34, no. 1, p. 25-31.

Cheatum, E. L., and C. W. Severinghaus
1950. Variations in fertility of white-tailed deer related to range conditions. Trans. Fifteenth N. Am. Wildl. Conf., p. 170-189.

Cronemiller, F. P., and G. A. Fischer
1946. Censusing a deer herd by sampling methods. Trans. Eleventh N. Am. Wildl. Conf., p. 349-354.

Dasmann, William P.
1949. Deer-livestock forage studies on the interstate winter deer range in California. Journ. Range Mgmt., vol. 2, no. 4, p. 206-212.
1951. Some deer range survey methods. Calif. Fish and Game, vol. 37, no. 1, p. 43-52.

Fischer, George A., John C. Davis, Floyd Iverson and F. P. Cronemiller
1944. The winter range of the interstate deer herd, Modoc national forest, California. U. S. Forest Service, Region 5, 20 p. (mimeographed)
1945. A supplement to "The winter range of the interstate deer herd." *Ibid*, 7 p. (mimeographed)

Hormay, August L.
1943a. Bitterbrush in California. Calif. Forest and Range Exper. Sta., Research Note 34, 13 p. (multilith)
1943b. A method of estimating grazing use of bitterbrush. *Ibid*, Research Note 35, 4 p.
1949. Getting better records of vegetation changes with the line interception method. Journ. Range Mgmt., vol. 2, no. 2, p. 67-69.

Interstate Deer Herd Committee
1946. Progress report on the cooperative study of the interstate deer herd and its range. U. S. Forest Service, Region 5. 11 p. (multilith)
1947. Second progress report on the cooperative study of the interstate deer herd and its range. Calif. Fish and Game, vol. 33, no. 4, p. 287-314.
1949a. Interstate winter deer range management plan. Calif. Fish and Game. vol. 35, no. 2, p. 103-114.
1949b. Third progress report of the cooperative study of the interstate deer herd and its range. *Ibid*, p. 115-134.
1950. Fourth progress report of the cooperative study of the interstate deer herd and its range. Calif. Fish and Game, vol. 36, no. 1, p. 27-52.

Latham, Roger M.
1950. Pennsylvania's deer problem. Pennsylvania Game News, Special Issue no. 1, 48 p.

Leopold, A. Starker, Thane Riney, Randal McCain and Lloyd Tevis
1950. The Jawbone deer herd: part 1 of final report on Pittman-Robertson Project California 28-R. In press.

Lommasson, T., and Chandler Jensen
1942. Determining the utilization of range grasses from height-weight tables. U. S. Forest Service, No. Region, 9 p.

McCain, Randal
1948. A method for measuring deer range use. Trans. Thirteenth N. Am. Wildl. Conf., p. 431-441.

Maloney, A. B.
1945. The fur brigade to the Bonaventura, John Work's California expedition, 1832-33. Calif. Historical Soc., San Francisco, Calif., 112 p.

Norris, J. J.
1943. Botanical analyses of stomach contents as a method of determining forage consumption of range sheep. Ecology, vol. 24, no. 2, p. 244-251.

Randle, Allan C.
1938. Deer winter range studies, 1937-38: Modoc National Forest, California Region. U. S. Forest Service, Region 5, 17 p. (mimeographed)
1939. Summary report on the winter mule deer range studies made during the winter of 1938-39. U. S. Forest Service, Region 5, 11 p. (mimeographed)

Rasmussen, D. I., and Everett R. Doman
1943. Census methods and their application in the management of mule deer. Trans. Eighth N. Am. Wildl. Conf., p. 369-379.

Severinghaus, C. W., H. F. Maguire, R. A. Cookingham and J. E. Tanck.
1950. Variations by age class in the antler beam diameters of white-tailed deer related to range conditions. Trans. Fifteenth N. Am. Wildl. Conf., p. 551-568.

Smith, Arthur D.
1950a. Sagebrush as a winter feed for deer. Journ. Wildl. Mgmt., vol. 14, no. 3, p. 285-289.
1950b. Feeding deer on browse species during winter. Journ. Range Mgmt., vol. 3, no. 2, p. 130-132.

Stoddart, L. A., and D. I. Rasmussen
1945. Deer management and range livestock production. Utah State Agric. College, Exper. Sta., Circ. 1211, 17 p.

NOTES ON KOKANEE SPAWNING IN DONNER LAKE, CALIFORNIA, 1949[1]

By J. B. Kimsey
Bureau of Fish Conservation
California Division of Fish and Game

INTRODUCTION

Although kokanee red salmon (*Oncorhynchus nerka kennerlyi*) were noted spawning along the shore in Donner Lake, Nevada County, in 1946, 1947, 1948, and 1949, it was not known whether or not the eggs would develop to hatching. J. C. Fraser observed them spawning along the shore in November, 1947 (Curtis and Fraser, 1948). After the spawning, however, the lake was drawn down very heavily in January and February and the nests were left dry and frozen. This same condition had been noted in 1946 by A. F. Pollitt of the Tahoe Hatchery of the Division of Fish and Game. From these observations it had been assumed that natural reproduction of kokanee in Donner Lake was virtually impossible.

On December 4, 1947, 5,190 eggs at 230 per ounce were taken from kokanee in Donner Lake and held for hatching at Tahoe Hatchery. One night during a particularly cold period, the water accidentally went off in the trough which carried these eggs and the next morning they were discovered in a shrunken, frozen condition. Instead of throwing out the supposedly dead eggs, the water was turned back into the trough to see if they would recover. The whole mass of frozen eggs rose to the surface and floated. After a time they thawed, swelled out to normal size, and went on developing. These eggs hatched with only a normal loss and the fry were later planted. The above observations were not recorded but were obtained from the different hatchery employees who handled the eggs.

Such an incident made it appear possible that if the eggs in the nests at Donner Lake were frozen or partially frozen for only short periods, they might continue development and that when the water again covered the nests they would hatch out and the resulting fry eventually would enter the Donner Lake fishery.

That the anadromous form of the red salmon (*O. nerka nerka*) was a successful lake shore spawner was well known, but little information on this phase of the kokanee's spawning habits was available.

OBSERVATIONS

With a view to obtaining definite information as to the success or failure of the shore spawning of kokanee in Donner Lake, extensive observations were carried out in the fall of 1949.

[1] Submitted for publication January, 1951.

One of the best areas for observing the spawning of kokanee in Donner Lake is located off the end of Waggoner's boat pier on the north shore. This area is only a few hundred feet from the highway and is easily accessible even through the heaviest of snow. The shore at this point slopes gently for about 100 feet and then drops off abruptly to depths of 30 to 50 feet. When the lake level is normal, the edge of the shelf is under about six to eight feet of water. The water is one to three feet deep over this point when the kokanee begin to spawn and the water surface is about one to one and a half feet below it at the point of maximum drawdown. The section where the observations were made is about 100 yards long and is composed of a mixture of sand, gravel, and cobbles on a clay substrate. About one quarter of this lies in a spring seepage area. Since the clay base is tipped slightly toward the lake, the gravel in the seepage area has a slow but constant flow of water through it.

The first kokanee were seen on the fourth of November, 1949, when the water temperature was 51 degrees F. at the surface. These consisted primarily of males and much fighting and splashing was noted. On the fifth of November a gill net was set in water from depths of six to fifty feet. When this net was picked up on November 6, eight male and one female kokanee were taken. All were in water shallower than 20 feet except the female, which was taken at 50 feet. The males had free flowing milt and the female emitted eggs on compression. The average size of all fish taken at this time was 18½ inches and the average weight was about two pounds. The coloration and body conformation were identical with those described for the anadromous form of the red salmon (Figure 109). No nest building was observed at this time.

Joseph U. Verret, student biologist, made an extensive reconnaissance of the lake shore on November 15, 21, and 29. He was unable to find any other kokanee spawning in the lake. However, a few were subsequently reported spawning in the northwest end.

FIGURE 109. Male kokanee in spawning condition, November 5, 1949

On November 15 and 29, Mr. Verret marked nine kokanee nests. On November 29 one of the nests was partially above the waterline and 200 eggs were removed. These eggs appeared to be in the "tender stage" and died soon after handling.

On December 7 all of the marked nests except two were exposed. Sample eggs were removed and were found to be developing normally.

At this time the eggs were buried under from four to seven inches of gravel. The water level of the lake was 10 inches below the surface of the nests. Even though the surface was dry, the eggs buried only four inches were kept moist by capillary water. The temperature of the sand in which the eggs were embedded was 39.5 degrees F. The surface of the lake was 47 degrees F., and the seepage areas 48 degrees F.[1]

On December 12 the top three inches of the nests were frozen. Below this level the sand was not frozen and the eggs were continuing development at 39 degrees F. The eggs in the seepage areas were still in 48 degrees F. water and several appeared to be in the first stages of "eyeing." The temperature of the lake was 45.5 degrees F.

Although no kokanee had been reported as spawning below the dam in Donner Creek, this area was investigated on December 12 and 20 live kokanee (14 males, six females) were observed. Three dead kokanee were also seen. At least six nests were noted in the first hundred yards of stream below the dam, and there were probably more. These kokanee appeared to be larger than those in the lake and were estimated to be from 18 to 20 inches long, with at least one individual about 24 inches in length. They were all in a very battered condition and were not laying eggs, although some flexing actions and fighting was noted among them. Most of them appeared to be so weak that they were barely able to maintain their position in the current. The temperature of the stream was 46 degrees F.

[1] Unless otherwise stated all lake temperatures were taken at the surface along the shore.

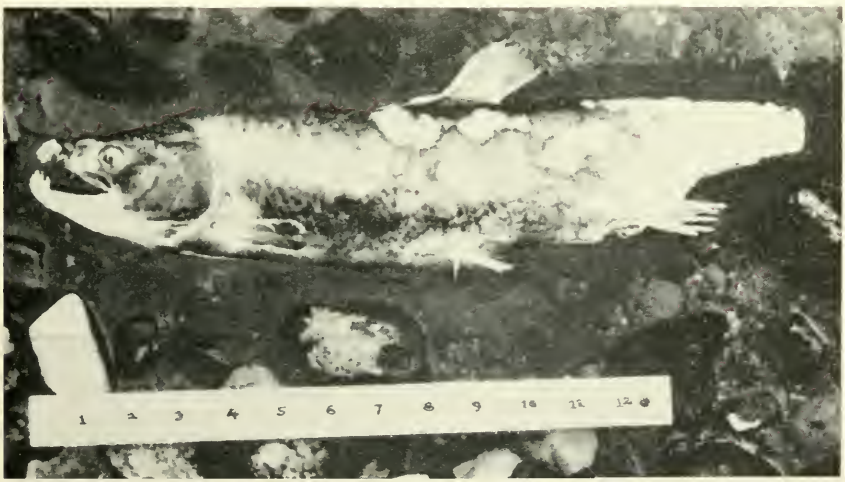

FIGURE 110. Male kokanee shortly after dying at the end of the spawning period. December 12, 1949.

On December 23 the air temperature was 47 degrees F., the lake 42 degrees F., and the eggs in the exposed nests 34 degrees F. The top five inches of nest were frozen and there was from one to three inches of snow on them. The eggs below this level were not frozen and appeared to be still developing. Although at least 10 kokanee had been observed on the 12th of December, none were noted this date. There were no dead fish along the shore. They may have been removed by coyotes, since tracks of these animals indicated that they had been prowling along the beach. The eggs in the seepage nests were not frozen and were continuing development at 45 degrees F.

On December 30 the air temperature was 42 degrees F. and the lake temperature was 42 degrees F. The eggs in the exposed nests were frozen so hard that they clanked like pebbles when dropped into a collecting pan. The eggs in the seepage areas were continuing development at 45 degrees F. and 44 degrees F. The top one-half inch of the seepage area was frozen, but the eggs were not. The top of the seepage nests was about one and one-half feet above the lake's surface, but the eggs were always in slowly running water.

Five kokanee were still alive in Donner Creek on December 30. The temperature of the stream was 39 degrees F. One dead male which measured 19 inches in length and weighed 2.8 pounds was picked up. Before the tail was frayed and the spawning period had begun, this fish was probably 20 inches long and nearer to three pounds in weight.

FIGURE 111. The exposed spawning gravels on December 30, 1949, when all nests were exposed and frozen

A brief observation on January 4 showed the eggs in the seepage areas to be in the eyed stage and developing at 44 degrees F. The air temperature was 33 degrees F. and the lake 40 degrees F. The other nests were frozen too hard to break through with a shovel in the limited time available. On January 6 the air temperature was 39 degrees F., and the lake was 40 degrees F. The seepage nests were 44 degrees F., and the eggs were developing normally. At this time a section 2 feet x 3 feet x 8 inches was excavated over a known nesting area. There were five inches of frozen sand over the eggs. Frozen eggs were obtained singly and in clusters at the bottom of this frozen level under rocks the size of hens' eggs. The eggs were all greatly shrunken and very hard. About 200 eggs were submerged in a pan in the lake. When they had thawed, they regained their round shape but turned white. A total of 1,073 eggs was obtained on this date. A careful count had been kept of all eggs previously removed from the same area, amounting to 354, giving a total of 1,427 eggs in six square feet. It was estimated that the eggs were laid in a belt 200 feet x 6 feet, or 1,200 square feet of nesting area. A conservative estimate based on this area would put the total number of eggs deposited at around 250,000. Mr. Jack Waggoner and Mr. Verret estimated that about 200 fish were spawning, with a sex ratio of one female to four males. Assuming 40 of these to be females and each female to deposit approximately 2,500 eggs, about 100,000 eggs would be deposited. Taking both figures into consideration, it would therefore be reasonable to assume that somewhere between 100,000 and 250,000 eggs were deposited. The actual number most likely lies in the lower range.

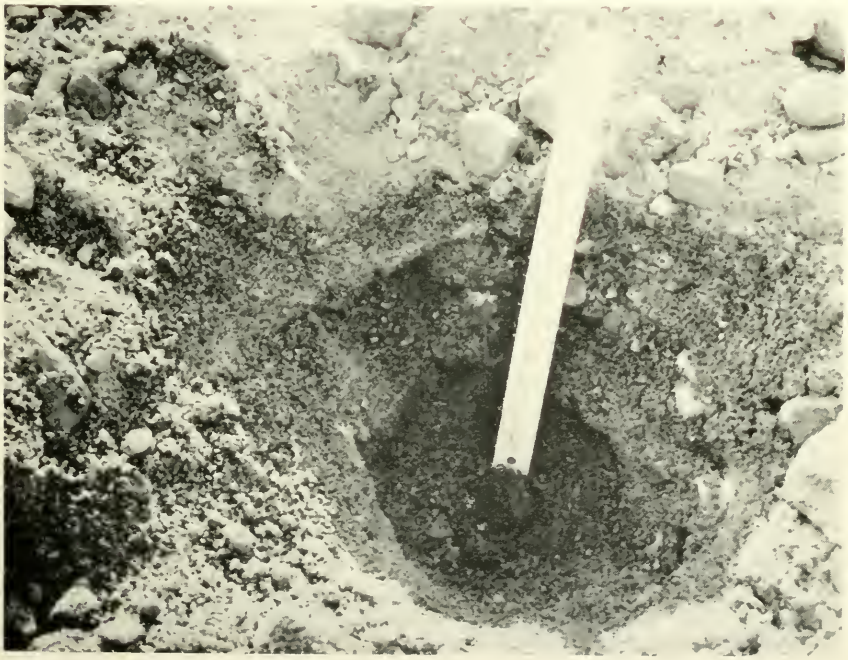

FIGURE 112. Nest frozen to depth of seven inches on December 30, 1949. All eggs here were killed.

On January 20, warm rains had accelerated the thaw and the inflow was evidently greater than the outflow, since the lake had risen one foot. This rise had flooded the lowest nests and capillary seepage again was keeping the higher nests moist and thawed. All of the eggs uncovered in the highest nests had turned white and appeared to be dead. The lower flooded nests still had live, developing eggs, in spite of the fact that they had been frozen solid for unknown periods of time. It would appear that at least the lower eggs in these nests were kept alive and prevented from freezing too long by capillary seepage from the warmer lake water. The eggs in these nests were at 40 degrees F. on this date, as was the lake water.

The seepage nests were at 44 degrees F. In searching for eggs, a number of empty ones were found. Very careful removal of the overburden of sand and stones resulted in finding one newly emerged kokanee and several others which were vigorously trying to emerge. All of the eggs (approximately 30) which were removed were very active and hatching appeared imminent. Ninety eggs were removed from the frozen nests near the shore and these, with the 30 seepage eggs, were taken to Tahoe Hatchery to hatch in the troughs.

On January 25 all nests were again flooded. As the lake came up, the excess deposit of gravel was washed off by wave action and the deepest eggs were buried three inches. An estimated 90 percent loss in eggs was caused by the freezing. It appeared that about 5 percent of the total nests were in the seepage area and another 5 percent of the total were in the lower belt of frozen nests, which continued development even though frozen.

On February 16 the air temperature was 42 degrees F. and the water under six to eight inches of ice was 34 degrees F. A number of holes were cut through the ice to observe the nesting areas. Two small fish-like objects were noted over the lower frozen nests. They were very active and would swim rapidly, coast to a stop on the bottom, and then resume swimming rapidly. At this time it was snowing and a wind made it difficult to make observations. One kokanee with yoke sac was obtained from the seepage nesting area. This individual was free swimming and very active. It was forced out of hiding by violently agitating the water with a shovel. The resulting current brought several out of the rock crevices, but only one was collected.

The eggs placed in the Tahoe Hatchery on January 20 hatched and the fry appeared to be normal in every respect. The average temperature of the hatchery water was 43 degrees F. The eggs from the seepage nests began to hatch on February 12 and those from the frozen nests began hatching on March 15.

SUMMARY

1. Kokanee in Donner Lake began spawning activities about the fourth of November, 1949, when the water temperature was 51 degrees F. at the surface.

2. The lake was drawn down to the extent that all nests were uncovered by December 23.

3. All of the eggs except those in the seepage areas experienced at least occasional freezing. Eggs submitted to prolonged freezing died.

4. Eggs in the seepage area developed normally at temperatures ranging from 44 degrees F. to 48 degrees F. They began hatching in the nests about January 20, 1950, and a series of eggs removed to Tahoe Hatchery began hatching in 43 degrees F. water on February 12, 1950.

5. Eggs removed from nests which had experienced little freezing began hatching on March 15, when removed to Tahoe Hatchery.

6. Kokanee fry from Donner Lake nests which were hatched in Tahoe Hatchery were normal in every respect, in comparison with the hatchery kokanee.

7. It is believed that the successful natural reproduction of kokanee would be possible on a large scale in Donner Lake if the water level could be stabilized during the spawning and developmental period.

LITERATURE CITED

Curtis Brian, and J. C. Fraser
1948. Kokanee in California. California Fish and Game, vol. 34, no. 3, p. 111-114.

EARLY DEVELOPMENT OF THE COTTID FISH, *CLINOCOTTUS RECALVUS* (GREELEY)[1]

By Robert W. Morris
Hopkins Marine Station of Stanford University
Pacific Grove, California

INTRODUCTION

Clinocottus recalvus was one of several species used in a study of methods of incubating the eggs and rearing the larvae of marine fishes in the laboratory. While the techniques involved were the primary field of investigation, some notes on development were kept during the course of the studies in order to add to the knowledge of identities of eggs and larvae of the fishes of California. A reasonably complete account has so far been recorded in the case of only this one species and this is here presented.

The invesigations were conducted during the winter and spring of 1949-50. Thus far the rearing experiments have been entirely of an exploratory nature. In none of them has the element of control been adequate. For these reasons a statement of methods would be premature at this time.

SOURCE OF MATERIAL

Six males and two females of *Clinocottus recalvus* were collected from tide pools in the vicinity of Carmel and Pacific Grove, California, over the period March 11 to March 17, 1950. They were placed in an aquarium supplied with running sea water and containing several large stones. On March 18 the aquarium yielded a cluster of eggs deposited by the larger of the two females, which was 95 mm. in total length. The smaller female, 82 mm. long, deposited a cluster the following day. These clusters were removed at the time of their respective discoveries and placed in separate bowls through which there was a steady, gentle flow of well-aerated sea water.

EGG CLUSTER

Both of the egg masses were wedge shaped and conformed snugly with the contours of the stones and aquarium bottom, between which they were deposited. The cluster laid by the large female covered an area roughly 20 mm. by 30 mm. and measured about 10 mm. at its thickest edge. The cluster from the small female was about 15 mm. by 25 mm. and also about 10 mm. thick at its thickest edge. By actual count, the cluster deposited by the small female contained 876 eggs. The eggs adhered firmly to each other but not to the substrate. In the small cluster the eggs were somewhat more firmly united than in the larger one, apparently due to a difference in the amount of adhesive material among them.

[1] Submitted for publication January, 1951. The writer wishes to express his gratitude for the guidance given by Dr. Rolf L. Bolin.

EGG

The eggs of both females were of the same pale, translucent, cream color with amber oil globules of a more transparent nature. This color may or may not be of value in identification since Budd (1940) and Eigenmann (1892) found considerable discrepancy in the color of the eggs of another species of this same genus. Eggs stripped from several specimens of *Oligocottus snyderi* Greeley have been seen which were identical in color with the ground color of the parent from which they came. They varied from pale green through olive to a deep violet. It may be that color will be of little value in the identification of the eggs of the species described in this paper.

No eggs were seen to be markedly distorted from the spherical shape. The mean diameter of 10 eggs from the larger female was 1.32 mm., and they ranged from 1.30 to 1.37 mm. The mean diameter of 20 eggs from the smaller female was 1.25 mm., and these ranged from 1.21 to 1.35 mm.

The areas of contact between the eggs were roughtly circular, ranging from .153 to .238 mm. in diameter with a mean diameter of .200 mm. in the case of the larger female, .221 to .306 mm. with a mean of .267 mm. for the smaller female.

The egg capsules were tough and extremely resistant to rupture and their thickness was found to be quite uniform at .032 mm. Radial canals are very evident even when examined under a wide-field binocular microscope. Each of these opens at the surface in a conical depression. At this comparatively low magnification the surface of the capsule appears smooth, but examination at the magnification of 440 diameters shows the texture to be granular. The individual elements of this granulation appear as beadlike nodes arranged in rows parallel in both vertical and horizontal coordinates. Superficially at least they bear strong resemblance to the rivet-shaped processes of the zona radiata in *Pygosteus pungitius* as described by Eigenmann (1890). Appearance of the capsule when examined under a magnification of 440 diameters is shown in Figure 113. The term capsule used in the above description implies the zona radiata and any other membranes which may have been in intimate association with it. A careful inspection revealed nothing answering the description of a micropyle; this may have been overlooked, however.

In describing the eggs of cottid fishes, Budd (1940) and Eigenmann (1892) have defined the number of oil globules present. This is not diagnostic in the eggs presently considered, the number varying greatly among the eggs at any one time during early stages of incubation. During these initial hours of embryonic development there is, in general, a steady decrease in the number of globules, accompanied by a concurrent increase in the size of those remaining. Although never actually witnessed, it is obvious that coalescence of the droplets takes place. During the last five days of incubation there is some decrease in the size of the remaining oil globule. Regarding the absolute quantity of oil initially present, there appeared to be some difference among the eggs.

The yolk, which imparts the creamy translucent color to the egg, is somewhat variable in quantity. This conclusion is made on the basis of the apparent difference in the size of the perivitelline space in the different eggs. The "opaque, grayish-brown mass of flocculent material" seen in the yolk of the eggs of *Orthonopias triacis* Starks and Mann by

Bolin (1941) is present in the eggs described in this paper. This mass is usually in intimate association with the embryo or one of the oil globules but this is not always the case. The yolk appears to become progressively more dense during development, due, apparently, to a constriction of the layer of protoplasm over it during the earlier stages of development and in the later stages to the confinement imposed by the extra-embryonic ectoderm. After about 70 hours the yolk has become so dense that the oil globules no longer rise freely through it but are held firmly in one position. That this density is not inherent to the yolk is indicated by the free movement of the oil globule after the larva has hatched. Protoplasm was not identified in the yolk.

EMBRYONIC DEVELOPMENT

The smaller egg cluster was broken into small pieces to facilitate counting and this harsh treatment resulted in the early demise of over half of the eggs it contained. Other than this initial heavy mortality in the one batch, development proceeded at a comparable rate in both clusters of eggs and further mortality was about equal. Water temperatures were taken daily during the course of incubation, and ranged from 13 degrees to 15 degrees C. The descriptions and the figures are based on eggs which were picked from the cluster at each examination. It was learned from early experience that the rate of development was greatly affected by the heat during the period of examination under the microscope. After eggs were once examined, they were placed in a separate container and not again used in recording the data on development.

The development can best be followed by reference to the accompanying figures.

Figure 114 represents an egg at the earliest stage observed. This stage is considered "zero" hours of development for the purpose of assigning the times to the other stages although the exact age of the egg represented here is not known. It is evidently very young and judging from the report of Bolin (1941) on *Orthonopias triacis*, development had probably been initiated within the previous hour. At this stage the yolk is drawing away from the capsule to form the perivitelline space. This space has a greatest width of about .20 to .25 mm and is completely formed in the first hour of recorded development. The behavior of the yolk indicates that the space is filled with a liquid of a slightly lower specific gravity than that of the yolk. At this early stage several large oil globules are present and rise freely through the yolk, while innumerable very small droplets lie at the periphery, their ratio of surface to volume being so great as to impede their rise.

During the period in which the perivitelline space is forming, the protoplasm over the surface of the yolk moves to form an elongate mass lying along a meridian. This movement is evident only by the accumulation of the protoplasm, no streaming of the latter being visible. The protoplasm moves without regard to gravity, indicating that it is of about the same density as the yolk. The accumulation of protoplasm in this meridian does not at first bulge into the perivitelline space but, rather, depresses the yolk. However, a short time later the flow continues to one end of the elongate mass where the blastodisc commences to form. This stage is shown in Figure 115, representing an egg after

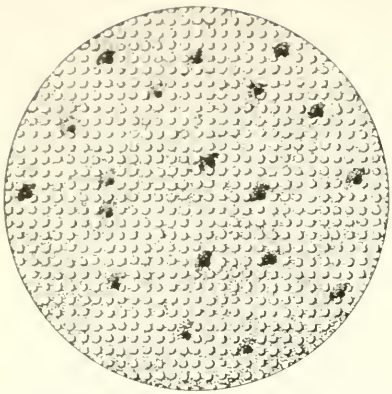

FIGURE 113. Egg capsule much enlarged. Entire field shown represents an area .05 mm. in diameter.

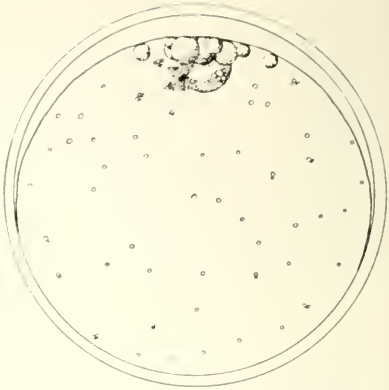

FIGURE 114. Egg at zero hours of development. Perivitelline space forming. Total diameter of egg 1.30 mm.

FIGURE 115. Egg at two hours of development. Protoplasm has converged in a general meridian and is moving to form the blastodisc.

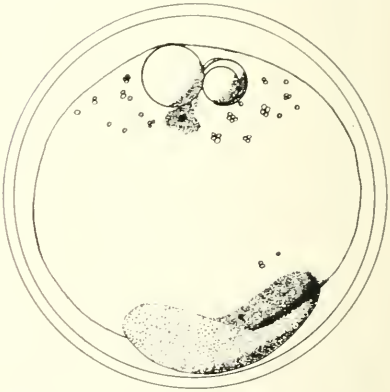

FIGURE 116. Four hours. Well-formed blastodisc.

FIGURE 117. Five hours. Two-cell stage.

FIGURE 118. Seven and one-half hours. Four-cell stage.

two hours of incubation. Here is seen the streak of protoplasm lying to the left and the developing blastodisc at its upper end. That the protoplasm remaining over the yolk is confining it closely is suggested by the furrow in the yolk which is produced by the early meridional accumulation of protoplasm.

After four hours the egg appears as shown in Figure 116. Here is seen a well-formed blastodisc with no traces of the surrounding protoplasm being visible.

Figure 117 shows an egg after five hours of incubation. At this time the first cleavage has taken place, and the first two blastomeres are to be seen. The first plane of cleavage is, obviously, meridional.

After seven and one-half hours, the egg appears as in Figure 118. By this time the second cleavage has been completed at right angles to the first.

Figure 119 depicts the egg after nine and one-half hours, at which time eight cells are fully formed. Six and seven cell stages are also commonly seen. In some eggs held under the microscope for prolonged observation, the third cleavage was seen to occur. It paralleled one of the first two cleavage planes, but differences in the rates of cell division caused the two developing furrows to be badly distorted. The first two planes were also displaced in this process, and a considerable loss of symmetry occurred. Whether the furrows of the third plane parallel the first or second cleavage is not known since four equally defined cells existed at the time this observation was begun.

At 11 hours an egg was observed with 16 well-defined cells. It is shown in Figure 120. At this time the blastomeres of the eggs observed were arranged in configurations of highly divergent nature. Twelve-, 13-, 14-, and 15-cell stages were encountered. Cells shifting over one another often obscured some of the others present.

At about 14 hours, the blastoderm recovered a high degree of symmetry. At this time, the first well-formed blastodermal cap could be seen. It is shown in Figure 121. It was, at first, lenticular in shape and later rose from the yolk becoming considerably more thickened. The number of cells contained in the cap could not be determined.

The egg shown in Figure 122 shows the condition at 24 hours of development when the late blastodermal cap consisted of cells greatly reduced in size. At this time, the cap was almost hemispherical in shape except that its periphery assumed a sharp gradient as it conformed to the contour of the yolk.

In Figure 123 appears a lateral view of an embryo at 57 hours. The posterior pole lies to the right where the embryo has become somewhat flattened. Encroachment upon the segmentation cavity by involution, particularly at the posterior end, causes the cavity to be clearly visible only at the left, forward of the anterior end of the embryo. The germ ring is prominent around the margin of the segmentation cavity. This ring is wide at the posterior pole of the disc, narrowing laterally and anteriorly. Manifestations of the phenomena associated with the formation of the periblast, as described by Wilson (1891), were not definitely observed although at the perimeter of the ring an area was marked off by a constriction forming a structure which somewhat resembled the description of a periblastic wall. This structure was obscured by the germ ring after a few more hours of development.

FIGURE 119. Nine and one-half hours. Eight-cell stage.

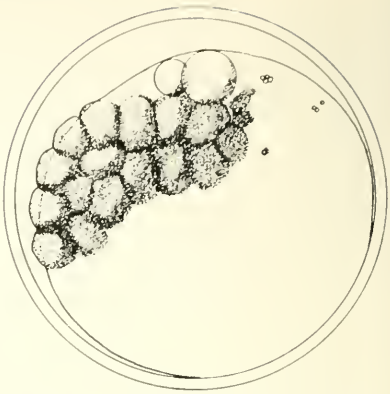

FIGURE 120. Eleven hours. Sixteen-cell stage.

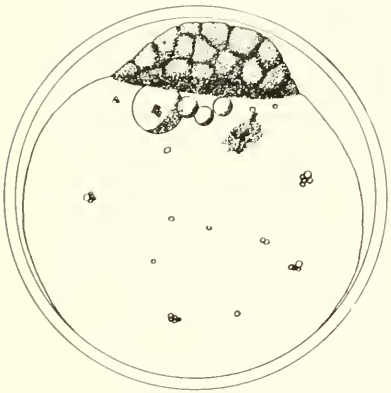

FIGURE 121. Fourteen hours. Early blastodermal cap.

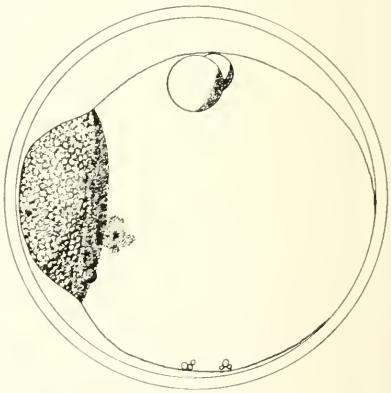

FIGURE 122. Twenty-four hours. Late blastodermal cap.

FIGURE 123. Fifty-seven hours. Segmentation cavity and germ ring.

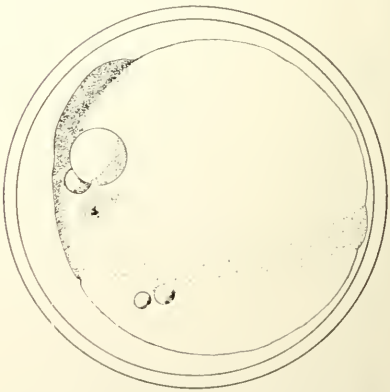

FIGURE 124. Seventy-three hours. Germ ring advancing past the equatorial position.

Figure 124 is of the right lateral aspect of the embryo after 73 hours of incubation. Differential growth of the germ ring is now quite evident. In this figure it has grown anteriorly, passing the equatorial position and can be seen to produce a slight constriction in the surface of the yolk. The restriction imposed upon the yolk by its increasing investment of extra-embryonic ectoderm apparently produces the increase in density earlier described. With this confinement the oil globules are rendered practically immobile.

At 88 hours the blastopore has closed and Kupffer's vesicle has become evident. There are profound changes in the anterior end of the embryo and the eyes have become visible.

A lateral aspect of the embryo after 96 hours appears in Figure 125. At this time the eye with its lens is clearly visible, and the posterior margin of the midbrain is marked by a noticeable constriction. Kupffer's vesicle is now and for a few hours following, at its peak of development. The remnant of the segmentation cavity persists at this stage as a clear area between the yolk and the extra-embryonic ectoderm, spreading forward and laterally from the anterior end of the embryo.

Parts of the central nervous system are more highly developed and segmentation of the body is clearly seen by the fifth day of incubation. Figure 126 represents an embryo at this stage.

The embryo on the sixth day is shown in Figure 127. The heart can be seen on the ventral surface of the body slightly posterior to the eyes and its pulsation is now regular and well sustained. The otic capsules are present, Kupffer's vesicle has almost lost its identity, and the tail is commencing to grow free from the yolk. Sporadic twitching movements can now be discerned.

Figure 128 represents an embryo of nine days. By this time the otoliths have become clearly visible and the tail, now growing free, has lengthened extensively and is twisted to lie flat on the yolk; it is quite active and moves from one side to the other. The last of the segmentation cavity can still be seen but it is obscured during the next day or two by the increasing growth of the tail. The eyes have now acquired some pigment and darken progressively from this time on. The yolk has become so dark at this stage that it is nearly opaque.

A dorso-lateral view of the anterior regions of the embryo at 15 days of incubation appears in Figure 129. Melanin, which first made its appearance over the body cavity on the eleventh day, has come to lie in large, well-defined, stellate chromatophores. Several dendritic melanophores of extremely delicate appearance now lie over the nape and also on the dorsal surface of the head just back of the eyes. A row of small melanophores lies along the ventral surface of the tail. The eyes have acquired sufficient pigment to be seen without magnification. The vitelline veins are quite prominent. The entire animal, but particularly the head, has undergone much growth. The granular patches on the surface of the head, seen by Eigenmann (1892) and other more recent authors, are now present. It was suggested by Bolin (1941) that these might function as rasping points to assist the embryo in extricating itself from the heavy capsule at hatching. In the case of the embryos considered here, this possibility seems unlikely. The granulations are minute convexities of low elevation which grade into the dorso-anterior surface of the head with a very gentle slope. They were first seen at 15 days of

FIGURE 125. Ninety-six hours. Eye and Kupffer's vesicle.

FIGURE 126. Five days

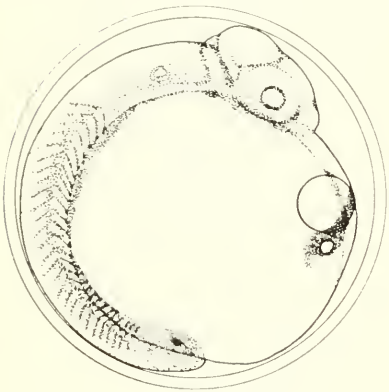

FIGURE 127. Six days

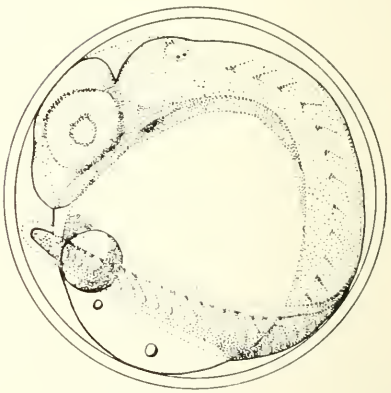

FIGURE 128. Nine days

FIGURE 129. Fifteen days

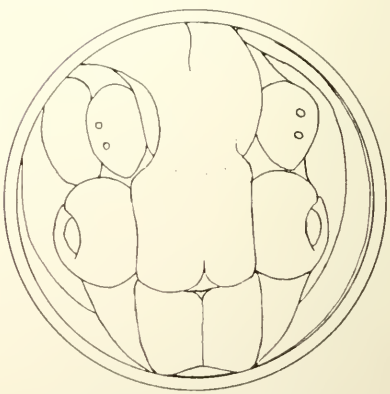

FIGURE 130. Nineteen days

incubation. Their location and approximate size can be seen in Figure 129. Later in this description they will again be discussed.

The delicate membranes of the pectoral fins were first seen on the sixteenth day. At this time they were visible only when the embryo was in such a position that they could be viewed against the clear perivitelline space.

HATCHING

An outline drawing depicting the proportionally large size of the head on the 19th day when the embroyos began hatching is shown in Figure 130. Good fortune was experienced in having an egg in advantageous position under the microscope and in perfect focus at the very moment of the initial rupture of its capsule. The head emerges explosively, but the remainder of the body may stay in the capsule for some time. When the head first comes out it is extremely flattened. The incipient lower jaw is crushed back and upward against the roof of the mouth. The dorsal surface of the eyes is almost level with the extreme top of the head. This great flattening was not noted at the time of the preparation of Figure 129; however, a retrospective examination of that figure indicates such a condition even at that early date. Immediately upon emerging from the capsule the head begins to round out and enlarge. Concomitant with this change in contour the granular patches on its surface largely disappear. After three or four hours only traces of crescentic and circular lines remain to mark their former position. It appears probable that these patches are merely distortions in the surface of the head which, though destined to be rounded, is greatly flattened by the extreme pressure which it suffers during its late stages of confinement. Measurement of the wall of the empty capsule indicates no decrease in its thickness during incubation, nor were any scores of erosion observed on its inner surface. It must be added, however, that it is difficult to avoid search for a structure, perhaps analogous to the egg-tooth of birds, which could facilitate the escape of the delicate larva from this extremely resistant capsule.

Hatching began on April 7 in the large cluster and during the following night in the small one. Shortly after the beginning of hatching the eggs were removed from running water and placed in a container of sea water, equipped with a mechanical agitator. Approximately 80 percent of the eggs hatched on April 7 and 8. Thus, with respect to both clusters, hatching occurred primarily on the nineteenth and twentieth days of incubation. Among those eggs remaining, some hatching continued for the next eight days, at the end of which time only a few living individuals remained. These were discarded. The larvae hatching after April 8 were much smaller than those which hatched the first two days. These late-hatched larvae were weak and inviable. Conspicuous was the difference in the size of the eye of the late individuals, the diameter of this organ being reduced by as much as one-third that of the eye in the healthy, early-hatched larvae. The late-hatched members are not considered in this description since they failed to develop.

LARVAL DEVELOPMENT

During the first eight weeks of larval development, water temperatures were taken once or twice daily. These temperatures ranged from 13.5 degrees to 17.5 degrees C. No greater change than 1.5 degrees C. was noted in any single period of 24 hours. After two months, water temperatures were no longer taken regularly.

To record their progress, larvae were examined briefly each day or two during their first four weeks. What appeared to be typical specimens were examined thoroughly and a drawing was prepared whenever development had proceeded to the point where such a figure would be useful. The course of development can best be followed by reference to these. In preparation of the drawings, well-defined outlines are shown by solid lines. Vague margins or the edges of hyaline areas are shown in stippled lines. Up to and including the figure of the larva at seven weeks of age (Figure 137), individual melanophores have been shown as accurately as possible. For the condition of the other pigments up to this time, the text must suffice. Stippled areas in these figures represent the relative opacity of those regions. In Figure 139 the chromatophores have become so numerous and relatively so small that, for the most part, their positions have been shown as stippled areas. It appears likely that with development there is a virtual as well as relative diminution in size of the melanophores, but their expansion and contraction makes this difficult to ascertain. Live specimens are shown in Figures 131, 132, 133, 134, 135 and 137. The remaining figures are of animals freshly killed.

NEWLY HATCHED LARVA

Figures 131 and 132 represent the newly hatched larva, with mean length of 4.65 mm. These larvae were at least two hours old, their heads having rounded out, and lower jaws having become functional. Although the lower jaw opens and closes, no stream of water can be seen passing through the mouth. The granular patches of the surface of the head remain only as faint delicate lines at this time. They are crudely depicted in the figures. Some of the parts of the central nervous system are well defined in the anterior regions, but back of the head the cord is not marked

FIGURE 131. Newly hatched larva. Total length 4.6 mm.

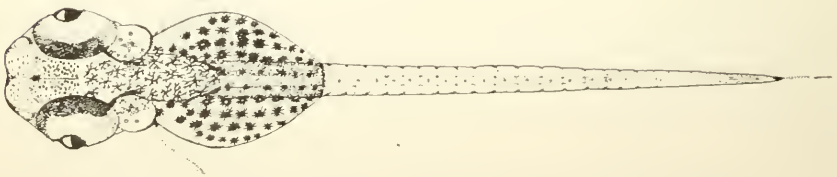

FIGURE 132. Newly hatched larva, dorsal view. Total length 4.7 mm.

off from the developing muscular tissue. The eyes are prominent and highly functional, and the choroid fissure is still evident, though reduced. The otic capsules and otoliths can be seen quite plainly. Neither olfactory capsules nor nasal pits are evident. Midway along the body, segmentation is quite obvious but grows increasingly less conspicuous both anteriorly and posteriorly. The finfolds are large and continuous, the ventral being slightly deeper than the dorsal one. The gut is small and has one loop embedded in the yolk. The liver is prominent and in some specimens a bright green gall bladder is to be seen. The oil globule moves freely in the anterior part of the yolk sac. During the preparation of the drawing, the larva usually come to rest in an inverted position, thus the oil globule in the figure is in the ventral part of the yolk. Normally, with the body upright, the oil globule comes to rest against the antero-ventral surface of the liver. Two to 12 diffuse, dendritic melanophores appear on the top of the head in the interorbital space, the pattern extending back to meet that over the nape where there are 13 to 19 pigment cells of the same general appearance. When they are all in an expanded condition, the melanophores over the nape are somewhat darker than those on the head. There are three to seven pale melanophores within each otic capsule. Three to five dendritic melanophores are situated on each side of the yolk sac antero-laterally, and 14 to 24 smaller ones extend along the ventral margin of the body beginning somewhere between the fifth and eleventh segment back from the vertical of the anus. The first one or two of these are usually separated from the remainder of this series by one or two unpigmented segments, and the last one to five extend diagonally down into the ventral finfold. Over the body cavity lies an elliptical pattern of large stellate melanophores. From a lateral view, this pattern narrows into a band anteriorly that is lost within the head and posteriorly into a band that curves downward following the descending gut. When seen dorsally as in Figure 132, about 35 to 50 of these large melanophores can be counted on either side, arranged in five to six reasonably well-defined rows. They tend to have clear centers and radial branches arising from a central ring of melanin. Even when fully expanded they are dark and well defined and do not lose their individual identities. On the surface of the descending gut, approximately 16 melanophores can be counted, and one is located on the lip at each side of the anus. The above-mentioned elliptical pattern in which these melanophores lie is formed by a matrix of xanthin, itself behaving very much like a large chromatophore. Conditions causing dilation and contraction of the melanophores, such as exposure to chemicals and sudden temperature change, cause the margin of the ellipse of xanthin to move in an undulating fashion. In death it is seen to be contracted, shrinking the entire pattern toward the midline. A small amount of diffuse xanthin is found on the nape and the top of the head. This pigment is not seen as well-defined chromatophores in these areas.

TEN-DAY LARVA

During the first 10 days after hatching the length increases by about one-half millimeter in most of the specimens and the yolk sac loses its broad lateral convexities, the yolk having been exhausted (Figure 133). An oil globule does not persist beyond five days after hatching. The intestinal loop has grown much larger, and food organisms can now be seen

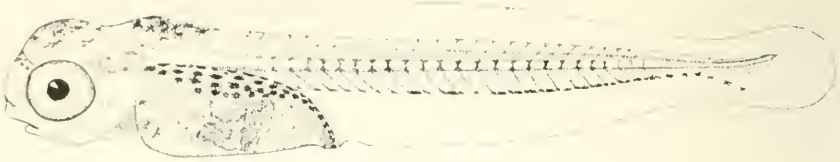

FIGURE 133. Ten-day larva. Total length 5.0 mm.

within it. Incipient elements of the operculum have spread down and back from the eye, almost obscuring the lower jaw when the latter is closed. No trace remains of the choroid fissure. The posterior reaches of the body have become deeper, and the dorsal nerve cord is now clearly defined from the developing muscle segments. The posterior end of the tail curves up slightly at this time. A change has taken place in the ventral finfold just back of the anus so that it now bears a slight indentation at that point. The contour of the head has changed somewhat as can be seen in the figure.

The melanophores have become heavier over the body cavity and the nape and increased in number on the top of the head while xanthin has become more intense in all of these areas. In addition, three or four melanophores have appeared on the wall of the forebrain just anterior to the eyes. Vitelline circulatory elements now form a vermiculate pattern over the liver which has grown posteriorly, replacing the yolk.

NINETEEN-DAY LARVA

Figure 134 shows a larva at 19 days of age. Differences in size among the larvae have now become evident, a few lagging noticeably in their growth. There has been a substantial increase in the relative size of the

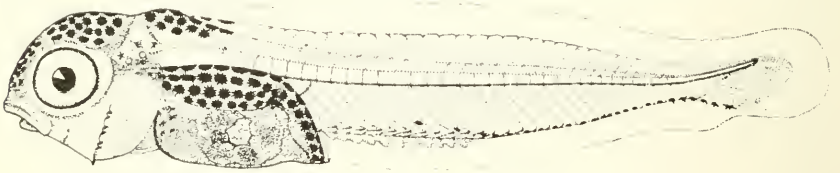

FIGURE 134. Nineteen-day larva. Total length 7.6 mm.

head and anterior regions of the trunk. The entire body has become markedly deeper. Branchiostegal rays, which were first observed at 14 days, can be seen clearly. The area below the eye has expanded broadly and formed a deep preopercle. The margin of this structure bears from five to nine short spines which are situated in clusters of two or three each. The preopercle has an acute-angled corner and in some specimens a well-defined spine is here formed. The eye is bright with accumulated guanin and its antero-dorsal surface shows a patch of metallic green. Back of the eye the chain of circumorbital bones has expanded considerably, its other parts remaining narrow. The otic capsule has assumed a triangular outline.

The gills can now be seen to be richly supplied with blood, and strong currents of water pass through the mouth when the jaws are opened and

closed. This current was first observed at 13 days. Whether or not respiration was confined entirely to the vitelline circulation prior to that time is not known.

Rays can be seen in the pectoral fins when the latter are seen against a light background. Just back of the vertical of the anus, 11 compressed nodes appear on the body margin. They originate from the ventral septum, one per segment. In later development it was noted that these are the ends of the interhaemal bones. In the region where these project, each myotome has assumed a sharp angle in its outline. The end of the tail now curves upward to a greater degree, and extending downward and to the rear are about 10 ill-defined rays which are represented merely by bars of material somewhat more opaque than the surrounding tissue, and which are expanded and contiguous at their distal ends. These changes in the tail have brought the melanophores, which formerly lay in the ventral finfold, into contact with the most ventral of the developing caudal rays. The anterior two or three melanophores of the series on the ventral surface are now found in the septum well up in the body away from the margin.

All of the melanophores in the anterior regions of the body have become much heavier. On each side, those over the body cavity curve down and sharply inward at the upper limit of the descending gut. The number of melanophores in this region appears to be unchanged. On the anterior surface of the head there are now about 25 to 30 melanophores, and 35 to 40 occur over the top of the head. The number of melanophores over the nape is about the same. With the increased forward extension of muscle segments, three or four melanophores from the surface of the cerebellum now come to lie on the surface of the muscles themselves. Much diffuse melanin is present below and medial to the otic capsules. Diffuse xanthin has increased in the regions where it was originally described.

TWENTY-SEVEN-DAY LARVA

A larva of 27 days appears in Figure 135. In total length it measures only 8.3 mm, but its increase in girth has been in much greater proportion. The spines on the margin of the preopercle have grown in length and can be seen to be united by a membranous web. The acute angle of the peropercle is lost and it is now quite broadly rounded. Other elements of the operculum can be seen just beyond the margin of the preopercle as a vague narrow crescent, poorly defined against the underlying gill membranes. The eyes are beginning to migrate dorsally and their anterior surfaces are covered with a heavy layer of melanin. The otic capsule is now a trilobate structure being encroached upon by the folds of the brain and the dorsal extension of the operculum.

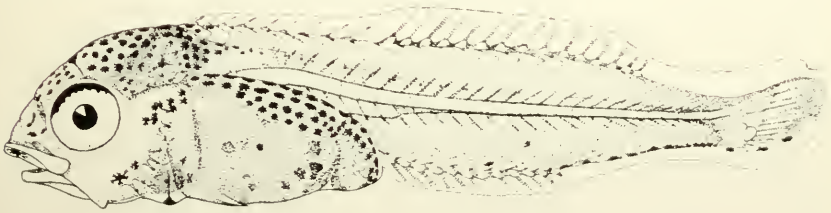

FIGURE 135. Twenty-seven day larva. Total length 8.3 mm.

The pectoral fins have grown to about 1.9 mm in length but have not acquired sufficient substance to be seen against the mottled background presented by the body. The pelvic fins have appeared as small flaps in the position shown in the figure.

The changes in the median fins have been great. From the ends of the interhaemal bones the soft rays of the anal fin can now be seen to be developing. They appear much like those of the caudal except that they are more widely spaced, hence more clearly seen. They are most dense and well-defined at their bases and become gradually less distinct at their distal ends where they fan out and grade subtly into the finfold. On the dorsum slightly posterior to the vertical of the anus, the soft dorsal rays are quite prominent. Development of the soft dorsal rays from the ends of the interneurals does not begin as early as the similar development described in the case of the anal fin; once begun, its rate is rapid and at the stage under consideration, the rays of the two fins are about equal in length. Growth of the soft rays into both finfolds has produced marked changes in the outlines of the latter as can be seen from the figure. The appearance of the spinous dorsal is quite different. The spines appear at the margin of the body, the ends of the interneurals remaining imbedded in the muscles throughout the entire development. From the outset, the spines have distal ends which are sharply defined and are thus easily distinguished from the developing soft rays. The appearance of the caudal rays has changed only in that they are now longer and slightly heavier and have less downward deflection, the end of the vertebral column having developed more upward curve. Their outgrowth has carried the caudal finfold beyond its original margin leaving the outline with a marked dorsal indentation. The haemal spines in the caudal region are compressed by this time.

A sharp angle has now developed in the outlines of almost all of the myotomes.

The melanophores present in earlier stages appear to be somewhat reduced in size by 27 days of development, although this reduction may be a relative one. At any rate, the larvae have a much lighter coloration. It might be of some significance to note that this change in coloration closely accompanies the assumption of the benthonic habit. A large melanophore has made its appearance on each premaxillary and the latter is clearly delimited from the maxillary. Melanophores have appeared on the opercular elements as shown in Figure 135. Melanin, both diffuse and in distinctive pigment cells, is abundant in the region medial to the otic capsules. The spinal cord is covered with heavy, diffuse melanin, and some well-defined melanophores extend over the anterior one-third of its length. The base of the pectoral fin has acquired some diffuse melanin. Much of the increasing xanthin over the head, nape, and body cavity now goes to form melanophores. The olfactory capsules are now clearly visible, and one or two melanophores appear at their respective margins. The nasal pits have also become clear.

THIRTY-FOUR-DAY LARVA

While Figure 136 was being drawn the animal died, and some distortion is to be seen in the region of the caudal peduncle and over the body cavity. In death, the body has become more opaque and the contours of the myotomes are lost. Little change is to be noted in the opercular

elements except that the margin of the preopercle now appears to follow the contour of the membrane which includes the preopercular spines rather than its original edge. The eye has continued its upward migration pushing ahead of the most anterior visible elements of the brain. The surface of the otic capsule has become darker, obscuring the detail medial to it.

The pectoral fins have now acquired sufficient substance to be seen in lateral aspect. The pelvic fins have increased in length, but details of their structure cannot yet be made out. Spines and rays in the median fins have continued to develop. The spines in the dorsal present the most conspicuous change, the ventrally and anteriorly located ones having outgrown those more posterior. Definition of the caudal rays has increased greatly and about 8 or 10 of the middle ones are divided into three segments. The posterior end of the vertebral column now forms a well-defined urostyle. The depth of the muscle segments has increased so as to almost cover the ends of all of the interneurals and interhaemals.

FIGURE 136. Thirty-four-day larva. Total length 8.8 mm.

Some melanophores have appeared on the surface of the otic capsule, other changes in their distribution on the head not adequately depicted in the figure. Melanophores have moved back over the dorsal surface of the body for about one-third the length of the spinous dorsal and two or three may be seen on the spines or membrane of that fin. Several melanophores now appear on the base of the pectoral fin and two or three well-defined rows of them can be seen out on the rays. Occasionally, one of the series of melanophores on the ventral edge of the tail has moved into the anal fin. The posterior two to five of this series now extend diagonally upward into the caudal fin and are in intimate association with the lower of its rays. Diffuse xanthin is abundant throughout the trunk and head, and traces are to be seen in the tail regions. Heavy xanthophores are present over the body cavity, lying in the interspaces between the melanophores there. They are also heavy over the head and extend down the spinal cord for about one-half its length, the individual xanthophores becoming smaller posteriorly.

At 30 days of development two small spines were noted to be growing out of the head directly over each otic capsule. These are shown in Figure 136. They attained a maximum length of about 0.4 mm. and appeared like developing cirri. However, they were transitional and at seven weeks a close inspection of the larva showed that they had atrophied. Their distal ends now bent back toward the body and they were encased in a low, fleshy cap. From this point on, their identity was completely lost. Also at about 30 days, there formed in the hyaline area

directly back of the descending gut a pencil-like downward extension of darkened material. It grew rapidly but developed some curvature and therefore did not extend below the venter. At seven weeks this had enlarged and developed more curvature and was assumed to be part of the urogenital system.

SEVEN-WEEK LARVA

Although it is not yet fully metamorphosed, the animal now leads an almost exclusively demersal existence.

The preopercle has undergone striking change. Its uppermost spine has lengthened greatly and to a lesser extent one or two directly below it have also grown. The remainder of the preopercular spines have become included in the solidified margin of the preopercle and cannot now be seen. The upper spines are still quite delicate and are difficult to make out in the lateral view, due to the increase of pigment in that area. The lower jaw extends below the angle of the preopercle and that angle is lost under a fleshy covering. The other elements of the gill covers have grown considerably but are as yet indistinguishable.

Among the specimens there is a great discrepancy regarding the position of the eyes at this time. In some they lie almost at the outline of the head but in most they are in about the position shown in Figure 137. The melanin cap of the eye now extends down on each side of the eyeball. Each of the olfactory capsules now bears a robust spine and both pairs of nares are visible.

The pectoral fins have become heavy with rays well defined in their proximal portions. The ends of the rays are still flattened and grade into the surrounding membrane, except the lowermost four or five which are clearly defined for their entire length. Segmentation is clear in all of the rays and the membrane is incised between the ends of the lower five. The pelvic fins have increased greatly in length and the rays can be made out but a spine cannot be seen.

In the spinous dorsal, the centrally located spines have become elevated and all spines have grown in length. In the soft dorsal and anal fins, the rays are divided into two or three segments and are clearly defined except at their distal ends where they are still flat and "brush-like." The caudal rays show comparable development except in the dorsal and ventral edges where they merge and are without separate identities. In the tail the haemal spines have fused into a hypural plate which has a conspicuous thickening extending down and back from the proximal end of the urostyle.

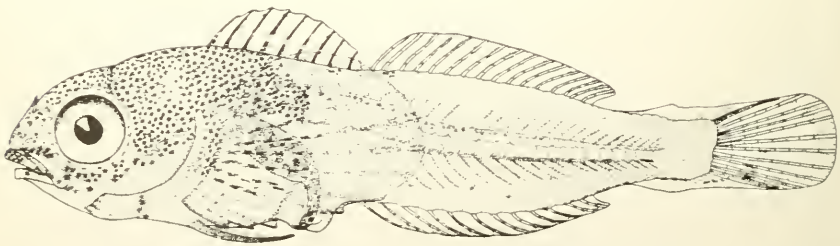

FIGURE 137. Seven-week larva. Total length 10.8 mm.

The melanophores over the body cavity are quite indistinct due to the increased thickness of the body wall. The distribution of the melanophores over the head is adequately shown in Figure 137. Large melanophores are found on the rays of the pectoral fins, forming three or four ill-defined bars across the latter. Over the dorsum, the posterior spread of melanophores from the nape has extended laterally and reaches midway between the origin of the pectoral fins and the anus. These melanophores extend forward over the base of the pectoral fin and are continuous with those which originated there. Melanophores lying in close association with the spines of the dorsal form three reasonably well-defined bars across that fin. A few small melanophores are also found in the membrane. Two small areas of melanophores are found on the dorsum near the junction of the spinous and soft dorsal fins. Little change is to be noted in the series of melanophores along the ventral surface of the tail except that the anterior ones are becoming obscured by the thickening of the body. Melanin on the spinal cord has continued to increase. Xanthophores have increased in number and have spread posteriorly so that they are now found over the entire body. Larger xanthophores are conspicuous on the spinal cord. The increase in intensity of the coloration of the xanthophores is steady and after the sixth week of development there were some which could probably be termed erythrophores. These reddish pigment cells are now particularly conspicuous over the head and along the lateral midline of the body, back to about the vertical of the anus. Guanophores made their appearance on the opercular elements of some of the specimens at six weeks of age and at seven weeks they are still difficult to study and can be seen only under optimum conditions. The pale, translucent green pigment common in the flesh of some cottids was first noted about the head and pectoral regions when the larvae were about six weeks old.

The anus has moved anteriorly and has caused the trunk to become somewhat shorter and deeper in relation to the size and shape of the head.

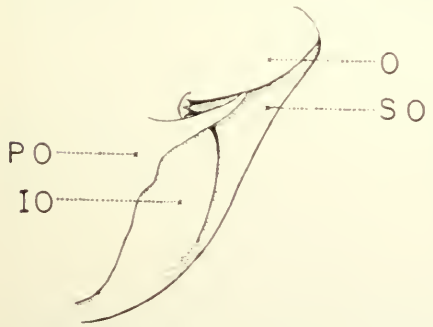

FIGURE 138. Opercular elements at eight weeks. PO = preopercle; O = opercle; SO = subopercle; IO = interopercle.

In Figure 138 appear the opercular elements at eight weeks of age. At this time the long spine of the preopercle is developing a slight upward curve and the remaining spines have been lost through ossification of their membranous investment. The bony divisions of the gill cover can be clearly seen.

Close examination of the pelvic fin at eight weeks shows the spine developing in intimate association with the first soft ray.

TEN-WEEK FISH

The larger specimens of 10-week-old fish are about 20.0 mm. in total length. The 18.0 mm. specimen represented in Figure 139 was killed prior to preparation of the drawing and as a result the rays of the pectoral fins are pulled together, the gill covers are flared, and the myotomes are obscured.

The preopercle with its one long curved spine is quite conspicuous. Growth of the tissues over the other opercular elements obscures their margins except for part of the line demarking the interopercle from the subopercle. The lower angle of the preopercle is also overgrown. The opercle now extends back and its upper lobe lies over the base of the pectoral fin. The principal exit of the water passing over the gills is marked by a wide, well-defined groove at the upper limit of the operculum. Both pairs of nares have developed definite tubes by this time.

The eyes have advanced so that they now form part of the outline of the head. Melanin in the eyes has increased somewhat, following the pattern previously described. The lower halves of the pectoral fins now have incised margins and their rays are well defined.

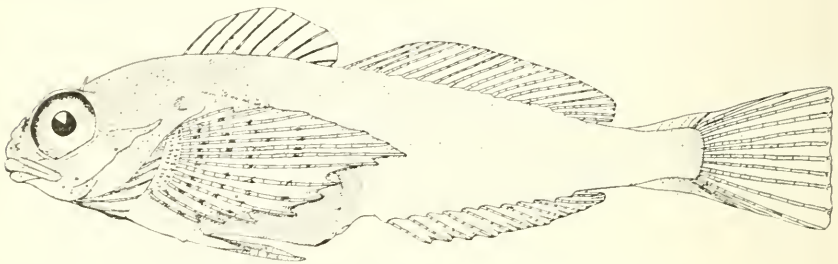

FIGURE 139. Ten-week fish. Total length 18.0 mm.

The membrane of the anal fin shows slight incision. The dorsal fins show no significant change. The caudal rays are well defined except at the distal ends which do not reach the margin of the fin. From their termination to the margin of the membrane, they are represented by delicate undulating lines, several of which extend out from the end of each ray. If such a condition existed in any of the other fins during their development, it was overlooked.

The large dendritic melanophores seen throughout the development in various parts of the body now persist only on the pectoral fin where they form three or four ill-defined bars on or close to the rays. Two rows of somewhat smaller melanophores are situated across the base of the pectoral fins. At this time the color of the fish is imparted dominantly by erythrophores which have shown great increase in numbers. They are now found on all parts of the body and occasionally a few are seen in the membranes of the fins. Whether or not the domination of this particular pigment is due to environmental conditions is not known. The general patterns followed by the red and yellow are the same. Over the head and anterior one-half of the trunk, xanthophores are abundant and in close association with the erythrophores. Posteriorly, the xanthophores are less frequent. Melanophores are also present in the concentrations of erythrophores over the areas where the former are shown in Figure 137, but their posterior spread has been, with exception of a few isolated individuals, masked by the increasing abundance of guanophores. These last mentioned pigment cells cover the melanophores quite effectively but are not prominent in the areas dominated by red and yellow. A concentration of guanophores forms a pale triangle over the head which is surrounded by broad, dark lines formed by concentrations of red, yellow, and black. The base of the triangle extends across

the head at about the posterior margin of the eyes, and its apex is formed by two dark lines converging just anterior to the origin of the spinous dorsal. The lateral angles of this triangle are directly above the spine of each preopercle. Heavy pigmentation covers the anterior surface of the head between the eyes and extends down to cover the anterior two-thirds of the upper jaws. The region of the operculum and preoperculum, below and behind the eye, is dominated by a broad band of guanophores. Posterior to the triangle mentioned above is a wide band of somewhat lighter coloration extending down and forward on each side from about the origin of the spinous dorsal. This is followed by a heavy saddle-shaped band of red. Posteriorly, bars alternately dominated by guanophores and erythrophores extend across the back. The red areas are continuous with a band of erythrophores which originates anteriorly around the base of the pectoral fin and passes posteriorly. This band has a wavy ventral margin. There is a rather isolated patch of red over the caudal peduncle. Along the sides of the body, about parallel with the vertebral column, is a band of erythrophores which follows the urostyle in the tail. There is also a vertical band of red down the side of the tail from the vertical of the end of the urostyle. The entire contents of the body cavity have assumed a heavy red color but this is perhaps imparted by the diet of copepods upon which the fish have fed.

Two pores of the lateral line system now appear in front of each eye and two can be seen in the interorbital space. A slender cirrus now appears over, and just posterior to, each eye. Well-defined scales occur along the lateral line from the posterior margin of the operculum to about the vertical of the anus. These scales become less distinct posteriorly.

FOURTEEN-WEEK FISH

Figure 140 represents a fish 14 weeks of age, measuring 24.3 mm. in total length. At this time it may be treated satisfactorily with the taxonomic keys of Bolin (1944). Color changes include heavier development of melanophores, guanophores, and erythrophores in the areas where they earlier appeared, as well as a general spread of melanophores caudally, the latter coming to occupy those areas formerly held by the red and yellow pigments alone. Bars of melanophores show plainly on the two dorsal fins and a similar effect produced by erythrophores is present on the caudal. Four or five bars of melanophores are present on the pectoral fins. The pelvics and anal remain unmarked. The ground

FIGURE 140. Fourteen-week fish. Total length 24.3 mm.

color of the entire animal is a yellowish green and is much lighter than that of adult specimens. The scales which appeared temporarily in the anterior one-third of the lateral line are overgrown by skin. The post-orbital cirrus of each side is now followed by three more cirri and three or four lie at intervals along the anterior part of the lateral line. The spine of the preopercle has become shortened and thickened. The anus lies well in the middle one-third of the distance between the base of the pelvic fins and the origin of the anal.

According to Bolin (1944), the young of *Clinocottus globiceps* (Girard), when at this stage of development, are indistinguishable from those of *Clinocottus recalvus* on the basis of morphology, and one must rely on the range to make the determination. This difficulty is due to the late development of cirri in the anterior half of the interorbital space in *Clinocottus globiceps*, these not making their appearance until the specimens are at least 35 mm. in length.

Beyond the stages of development dealt with in the present paper, adequate descriptions are to be found in the literature.

REFERENCES

Bolin, Rolf L.

1941. Embryonic and early larval stages of the cottid fish *Orthonopias triacis* Starks and Mann. Stanford Ichthyol. Bull., vol. 2, no. 3, p. 73-82, 25 figs.

1944. A review of the marine cottid fishes of California. *Ibid.*, vol. 3, no. 1, p. 1-135, 40 figs.

Budd, Paul L.

1940. Development of the eggs and early larvae of six California fishes. Calif. Div. Fish and Game, Fish Bull. 56, 53 p., 13 pls.

Eigenmann, Carl H.

1890. On the egg membranes and micropyle of some osseous fishes. Harvard Mus. Comp. Zool., Bull., vol. 19, no. 2, p. 129-154, 3 pls.

1892. The fishes of San Diego, California. U. S. Nat. Mus., Proc., vol. 15, no. 897, p. 123-178, 9 pls.

Wilson, Henry V.

1891. The embryology of the sea bass (*Serranus atrarius*). U. S. Fish Comm., Bull., vol. 9, 1889, p. 209-277, 20 pls.

PLASTIC DETERIORATION AND METAL CORROSION IN PETERSEN DISK FISH TAGS[1]

By A. J. Calhoun
Bureau of Fish Conservation
and
D. H. Fry, Jr., and E. P. Hughes
Bureau of Marine Fisheries

INTRODUCTION

Petersen-type tags are currently being used extensively along the Pacific Coast from California to Alaska in connection with fish tagging programs ranging from very simple migration studies to elaborate and precise population determinations. They have been used on more than 30 species of fishes in California alone.

These tags consist of two plastic disks held against the fish by a pin through both disks and some part of the fish's body—usually the base of the dorsal fin or the caudal peduncle. The disks ride on the pins like wheels on an axle. A tag in place on a starry flounder is shown in Figure 141.

For some time the writers have been disturbed by the loss of tags due to corrosion of the pins in salt water and to breakage of the disks, and the effect that such losses could have on the validity of conclusions drawn from certain types of tagging experiments. This concern led to the aquarium testing of various metals commonly used with Petersen disks and to the critical examination of disks and pins returned from fish tagged at sea which, in turn, provided the material for this progress report. Results of corrosion and deterioration tests accumulate slowly, and it seemed desirable to make this information immediately available to other fisheries workers who may be unaware of the serious shortcomings of some of the metals and plastics in common use for these tags.

It should be noted in passing that the writers do not believe that the Petersen disk is an ideal fish tag, even when it stays free of metal corrosion and plastic breakage. The design has many disadvantages. It is slow to apply, does not allow for much growth of the fish, and is overly apt to catch on nets. Some advantages are that it is less apt to be overlooked than any other well-tested design, and that it can be attached to a wide variety of fishes. In certain tagging programs the disadvantages are serious, and efforts are being made in California and elsewhere to develop a different type of tag which will overcome them. Meanwhile, disk tags are commonly the most suitable type available; hence their widespread use.

We wish to express our appreciation to Dr. E. S. Herald of the Steinhart Aquarium, San Francisco, and to members of his staff for

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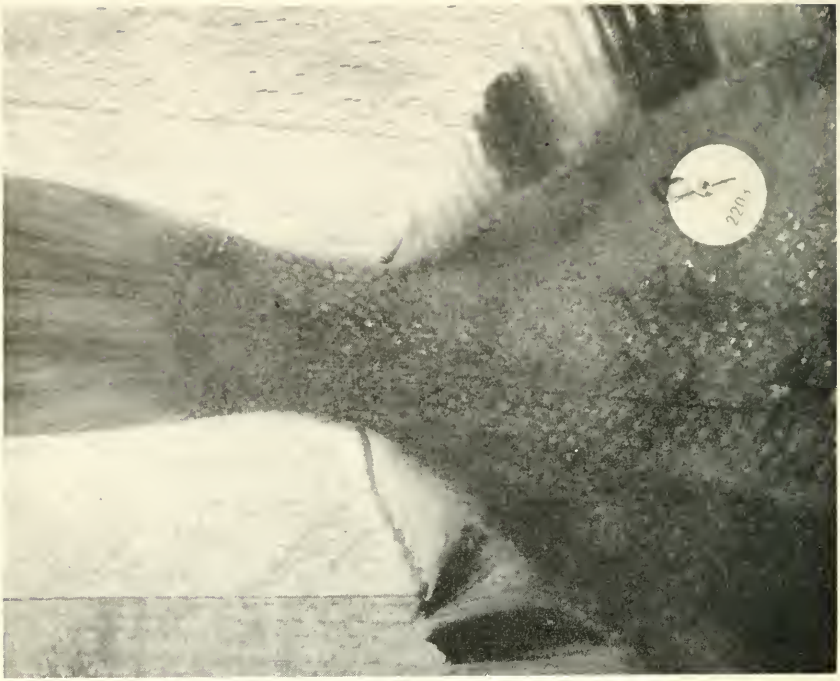


FIGURE 141. Starry flounder (*Platichthys stellatus*) with Petersen disk tag in place. The wire passes through the fish and holds a second disk in place on its far side. The knotlike twist of the wire shown here is in general use on the Pacific Coast. *Photograph by D. H. Fry, Jr.*

their wholehearted cooperation. Without the facilities of the aquarium, the work would have been far more difficult and less conclusive.

DETERIORATION OF PLASTIC DISKS

The disks used by the California Division of Fish and Game have been fabricated from several different materials. They are cut from plastic sheets built up of three thin laminations. One member of each pair is serially numbered and the other carries brief instructions to the finder. The printing is on the middle, opaque layer, and the two outer layers are transparent. Laminating serves the double function of protecting the printing and strengthening the disk. This design has been used widely and found to be generally satisfactory.

Cellulose Nitrate

The earliest disk tags used by the Division were made of cellulose nitrate (celluloid). They were a half inch in diameter (12.7 mm.) and 0.030 inches thick (0.76 mm.). They proved entirely satisfactory for the first few years after manufacturing. However, after six to eight years of storage they became somewhat brittle, and an appreciable number of those placed on salmon cracked while the fish were on the spawning beds. No cracking was noted when some of these same tags were used recently on striped bass. Much smaller numbers were involved in the latter instance, and the tags were not subjected to the battering they received on spawning salmon.

In a more recent order of cellulose nitrate tags, the disks were larger ($\frac{9}{16}$-inch diameter). They showed no tendency to crack in spite of the extra strain imposed by the larger diameter.

The desirability of greater thickness in nitrate tags to further increase their strength remains to be evaluated.

Two later orders were filled with cellulose acetate and with Vinylite disks, used by others and presumed to be satisfactory. They have had serious shortcomings, which are outlined below, and recent efforts to reorder nitrate tags have met with difficulties; few manufacturers will now handle the material because of the fire hazard involved. Moreover, with the advent of the newer, less-inflammable plastics, nitrate is becoming increasingly difficult to obtain in sheet form. A manufacturer willing to fill an order for nitrate tags has recently been located. However, judging from the difficulties encountered in locating this source, they may eventually be unobtainable.

Cellulose Acetate

Our first acetate tags were $\frac{9}{16}$-inch in diameter and 0.030 inch thick. Workmanship was excellent, but the acetate was softer and more flexible than the nitrate. Moreover, this material absorbs a relatively large amount of water, scarcely an advantage in a plastic fish tag. These acetate tags were satisfactory on flatfish, but they were an alarming failure on salmon. After a spawning migration which is often long and rough, the salmon dig nests and fight vigorously on the spawning grounds. The final result is that they damage the acetate tags to an extent unapproached by any other species studied. Almost as many salmon were recovered in the spawning grounds with fresh tag scars and no tags as with tags still in place. Most of the disks recovered were battered, cracked, and ready to fall off. Typical examples are shown in the bottom row in Figure 142. Pin corrosion may have caused shedding in a few instances, but most of the loss could be attributed with certainty to failure of the disks. Frequently, one disk would break off entirely, and the other would be recovered with the pin. Most of these salmon were tagged in fresh water and recovered so soon that pin corrosion was not a consideration. Such fish could be distinguished by absence of the adipose fin, which was removed when they were tagged.

Following this unfortunate experience with cellulose acetate, we decided to return to nitrate tags, but at that time we were unable to find anyone who would make them. In desperation, an order was placed for cellulose acetate disks a half inch in diameter and 0.045 inches thick, the maximum thickness which the maker's lamination press could handle without spoiling the printing. It was hoped that the reduced diameter and increased thickness would give greater strength. These tags have proved reasonably successful even on salmon. They show far more scratches, cuts, and wear than do the nitrate disks, but they will get us by if nitrate cannot be obtained. Twenty king salmon carrying these thick acetate disks were recovered after spawning by Marine Fisheries field men. One tag was missing and one was damaged enough to weaken it slightly. The remaining 38 were in good condition. Twenty-five tagged king salmon were among the fish taken for spawning purposes by the Coleman Hatchery crew. There was one tag missing and one bent and cracked. The remaining 48 were in good condition. Salmon held in a

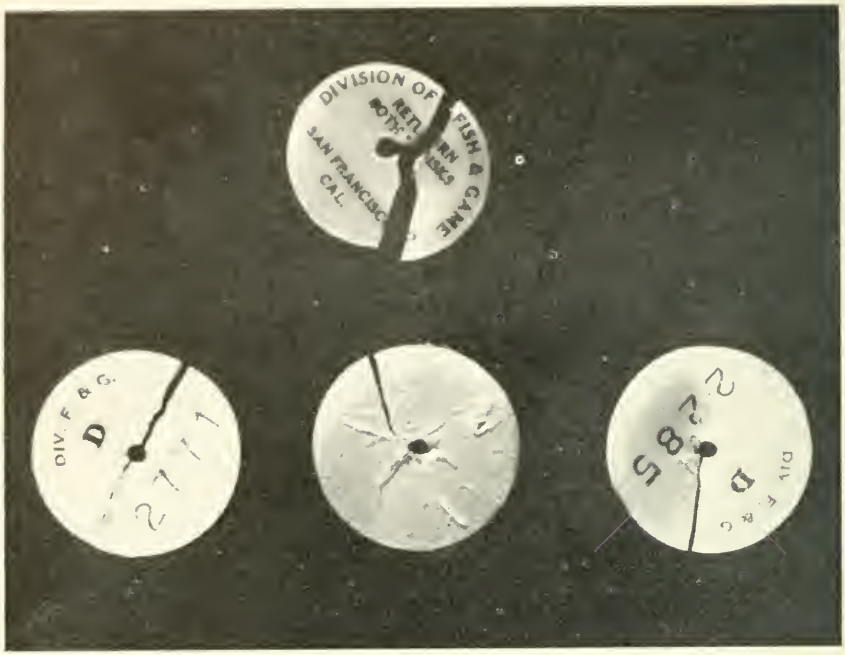


FIGURE 142. Defective tags. The single disk in the top row is Vinylite and broke while on a striped bass (*Roccus saxatilis*). Note the sharp fracture, which is typical of this material. The three tags in the bottom row are cellulose acetate (0.030 inch thick, 9/16 inch diameter). They were recovered from spawned-out king salmon (*Oncorhynchus tshawytscha*) and are all too typical of thin acetate tags recovered on the spawning beds. *Photograph by D. H. Fry, Jr.*

hatchery pen will damage tags but usually the collective damage is not as severe as on the spawning grounds.

Vinylite

While men working with salmon were having trouble with cellulose acetate tags, another crew was tagging striped bass with Vinylite disks of the sort used earlier for this species on the Atlantic Coast (Merriman, 1941). They proved to be unduly brittle. Sharply cracked disks were returned frequently. The one shown in the top row in Figure 142 is typical. Use of this material has been discontinued in favor of cellulose nitrate, for which a source has recently been found. However, if the latter cannot be obtained in the future, it will be desirable to compare the qualities of the thicker (0.045 inch) acetate tags with Vinylite ones of the same thickness. The brittleness of the latter material may prove to be less of a disadvantage than the weakness of acetate.

CORROSION OF METAL WIRES

Corrosion tests have been performed at the Steinhart Aquarium on Monel wire of two types, nickel pins of two batches, nickel wire, stainless steel wire and tantalum wire. Some Monel strap tags were also tested. Of these, only stainless steel and tantalum show real promise.

The tests were carried out by tagging striped bass (*Roccus saxatilis*) about 15 inches long, and examining them at such irregular intervals as our other work would permit. Tags were attached under the first dorsal

fin, under the second dorsal, and on the caudal peduncle. Most of the fish had three sets of tags.

Some of the metals used in these tests are commonly supposed to be rather immune to the action of sea water but actually corroded rapidly to the point of failure. Such corrosion appears to have been at least partially due to a concentration-cell effect. This phenomenon is related to the much better known galvanic action. Galvanic action occurs when two unlike metals are immersed in an electrolyte such as sea water. A concentration-cell action occurs when one metal is immersed in two concentrations of an electrolyte or in two unlike electrolytes. The body fluids of the fish and the ocean water are evidently sufficiently different to cause such corrosion in some metals which would easily withstand a simple immersion test.

The writers considered the possibility that conditions in the aquarium might be more corrosive than in the ocean, and that corrosion of one metal might vary among different species of fishes; hence, careful examination was made of returned tags from all the fish being recovered in central and northern California. This demonstrated that nickel pins corroded more rapidly in the aquarium than in the ocean, but they did corrode in both places. This difference could not be demonstrated with other materials. As possible reasons for the difference, we might mention that by comparison with the ocean off central California, the aquarium water averages a few degrees warmer, is less well buffered, and contains far more excretory products. In addition, the aquarium tanks have metal drain pipes, which might induce a minor amount of electrolysis. Also, the pins were only on striped bass in the aquarium tests and only on other species in field tests.

As for the relative effects of different species of fishes on corrosion in general, we can state that nickel pins showed serious corrosion when used on such unrelated forms as sharks, sturgeon, salmon, striped bass, and flatfishes.

Nickel

Nickel has been used widely in tagging marine fishes. Its shortcomings have apparently not been generally appreciated. In aquarium experiments begun in 1949, 20 of the nickel pins then in use in California

TABLE 1

Chemical Composition of Nickel Pins and Nickel Wire[1]

	Nickel wire	Nickel pins (Soft, for use on flatfish)	Nickel pins (Medium hard, for use on salmon)
Nickel	99.05%	99.11%	99.19%
Manganese	.30% to 3%	.30% to 3%	.30% to 3%
Copper	.03% to 0.30%	.03% to 0.30%	less than .03%
Iron	.03% to 0.30%	.03% to 0.30%	.03% to 0.30%
Cobalt	.03% to 0.30%	.03% to 0.30%	.03% to 0.30%
Titanium	less than .03%	less than .03%	less than .03%
Magnesium	less than .03%	less than .03%	less than .03%
Molybdenum	less than .03%	less than .03%	less than .03%
Silicon	less than .03%	less than .03%	less than .03%
Aluminum	less than .03%	less than .03%	less than .03%
Chromium	less than .03%	less than .03%	less than .03%

[1] Analysis by Abbot A. Haules, Inc., San Francisco. Elements other than nickel were determined spectrographically.

were tested with plastic Petersen-type disks on striped bass, as previously described. The diameter of these pins was 0.032 inch. Their chemical composition is given in Table 1. Ten pins of each of the two types shown in the table were used. These tags were placed beneath either the first or second dorsal fin. At the end of seven months, the fish were removed for careful examination of the various kinds of wire which were being tested. Nineteen of the 20 tags in which the nickel pins had been used had fallen off as a direct result of pin corrosion. The single remaining one was so badly corroded that the tag was on the verge of falling off. Typical examples of these corroded pins are shown in Figure 143, A to E. There was a peculiar hollowing out of many pins, leaving only a tissue-thin shell of metal for part of their length. This hollowing was the most common type of corrosion encountered in nickel pins in both field and aquarium. A fair proportion of those corroded in this manner were mirror bright on the outside and showed no external break that could be detected with the naked eye. Most such pins were discovered by bending the wire—the hollow ones broke. It is interesting to note that nickel wire which had not been formed into pins showed no such behavior.

At the time that these experiments were started, the Bureau of Marine Fisheries was getting returns from fair numbers of ocean-tagged salmon and assorted species of bottom fishes. Disk tags and nickel pins had been used exclusively. The returned pins were classified as uncorroded, corroded but not seriously weakened, or seriously weakened by corrosion. Tarnish was not classified as corrosion. The record of 158 salmon tag pins is shown in Table 2 and 75 pins from nine species of bottom fish are recorded in Table 3. Some bottom fish returns were out over 400 days and some salmon returns were out over 700 days.

FIGURE 143. *(opposite page)*

A. Nickel pin, 0.032 inch (0.81 mm.) diameter, field test. Note the longitudinal crack, under which the pin was hollow. Such cracks are difficult or impossible to see with the naked eye. This pin was on a green sturgeon (*Acipenser medirostris*) for 198 days.

B. Nickel pin, 0.032 inch (0.81 mm.) diameter, field test, after 151 days on a king salmon (*Oncorhynchus tshawytscha*). The shaft has hollowed near the head of the pin.

C. Nickel pin, 0.032 inch (0.81 mm.) diameter, field test, returned from an English sole (*Parophrys vetulus*) after 273 days. This pin is hollow near the tip, and a thread was passed through the nearly detached piece at the end to demonstrate its hollowness.

D. Nickel pin, 0.032 inch (0.81 mm.) diameter, field test, showing surface corrosion. This pin was on a king salmon for 492 days.

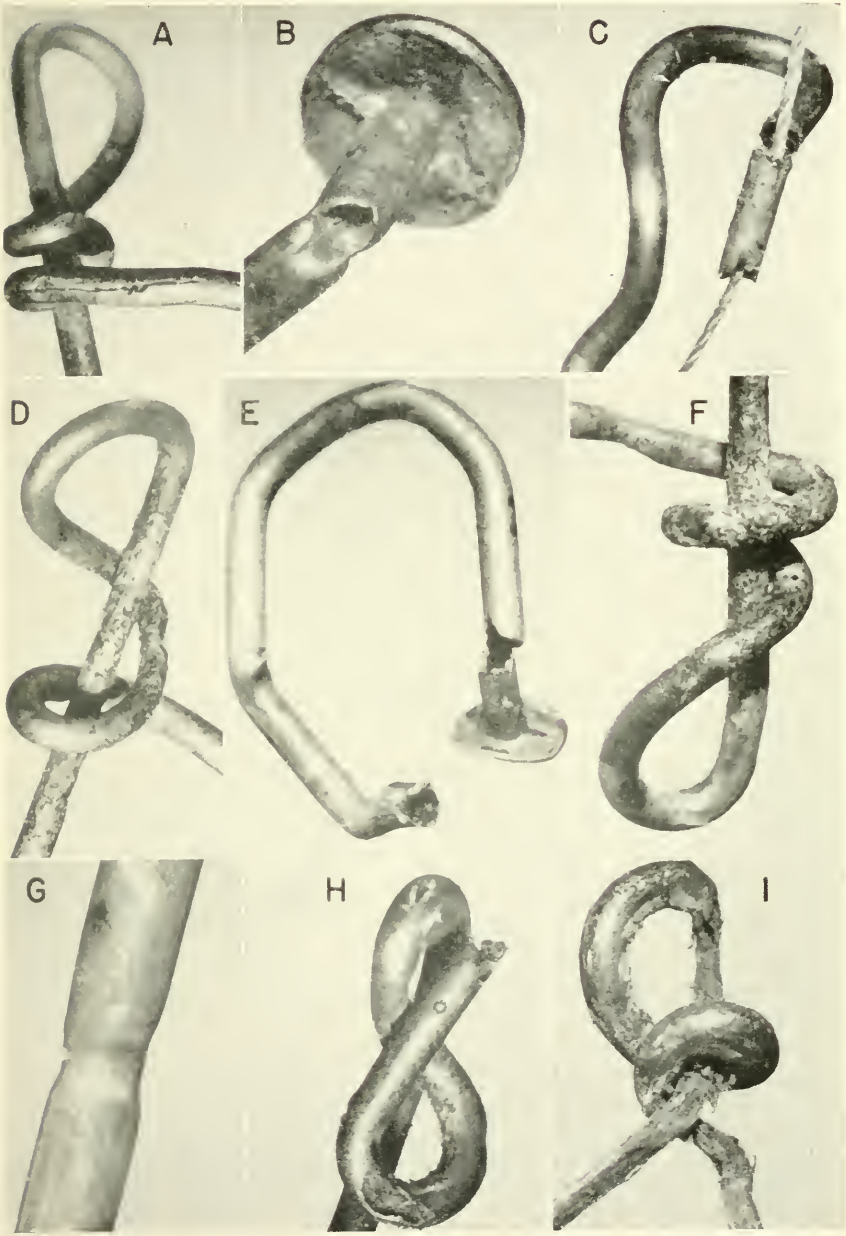
E. Nickel pin, 0.032 inch (0.81 mm.) diameter, aquarium test, showing hollowing at both ends. It was hollow for 5/16 inch at the tip. It was placed on a flatfish in the aquarium and found on the tank bottom 232 days later. Though in the aquarium, this fish was not used in the regular series of tests outlined in the text.

F. Nickel wire, 0.036 inch (0.91 mm.) diameter, field test, returned after 205 days on a 29-inch striped bass (*Roccus saxatilis*). Note the surface corrosion. Unlike the pins, the wire did not become hollow.

G. Hard silver wire, 0.036 inch (0.91 mm.) diameter, field test, showing an incipient break resulting from repeated bending. Similar "necks" in two returned wires broke in handling before they could be photographed. The one shown was prepared by flexing a piece of the silver wire. One wire reached this condition after 132 days on a 22-inch striped bass in the field.

H. Monel wire, 0.036 inch (0.91 mm.) diameter, field test, showing a pitting type of corrosion. Note that the tip has corroded through and dropped off. This tag was returned after 228 days on a striped bass.

I. Monel wire, 0.036 inch (0.91 mm.) diameter, aquarium test, after about seven months on a striped bass. Note the shredding type of corrosion. All tags in this test involving Monel had fallen off within 232 days from corrosion, and were collected from the tank bottom. *Photograph by D. H. Fry, Jr.*


A
B
C
D
E
F
G
H
I

There appears to be no demonstrable difference between species. Of the pins which had been out more than 200 days, corrosion had affected 34 percent of those on salmon and 32 percent of the ones on bottom fishes.

TABLE 2

Corrosion of Nickel Pins on Salmon

	Days out				
	0-99	100-199	200-499	500-799	Total
Number with no corrosion	42	56	22	15	135
Number corroded but not seriously weakened	0	1	2	3	6
Number seriously weakened by corrosion	0	3	8	6	17
Total examined	42	60	32	24	158
Percentage showing any corrosion	0	6.7	31	37.5	

Also of interest was the tendency of the incidence of corrosion among returned pins to level off (at something over 30 percent), rather than to continue increasing indefinitely. One plausible explanation is as follows. Suppose that the pins remain uncorroded for a period which varies greatly but is always over 100 days, and that each day thereafter a small number starts to corrode. The number of corroded pins will then increase as time passes, but eventally the corroded pins will start breaking. If the number breaking each day is the same as the number starting to corrode, there will be no further increase in the number of corroded (but unbroken) pins.

Nickel wire 0.036 inch in diameter cut into lengths and knotted at both ends has also been used in a preliminary way on striped bass in California. This material was tested in the same aquarium experiment with the nickel pins described above and stood up a great deal better. None of the nine wires tested showed any evidence of corrosion after seven months. Even after 19 months, the four which remained on fish appeared as good as new; nor had the other five which had been removed along the way been corroded. Differences in the chemical composition of the pins and the wire were at first believed responsible for the apparent discrepancy. However, this was ruled out when a chemical analysis, outlined in Table 1, revealed no differences of any consequence. Location of all the wires on the caudal peduncle, and all the pins further forward on the back of the fish, where they passed through more tissue, may have had something to do with it, although this seems improbable. Further confusion arises from the fact that badly corroded tag wires cut from this same coil have been returned from wild striped bass after less than a year. An example is shown in Figure 143F. This latter fact, coupled with the behavior of the nickel pins, already discussed, is proof enough of the general unsuitability of this metal for salt-water tagging. Work with it has accordingly been discontinued, despite the many intriguing questions which remain unanswered.

Monel

On the basis of information provided by the International Nickel Company, Monel metal appeared to be a promising material for use with Petersen disks on salt-water fish. A representative of this company recommended it highly in 1948. He was convinced of its superiority over nickel for our purposes. The success experienced with Monel strap tags on halibut (Thompson and Herrington, 1930) supported his conviction. Accordingly, this material was tried in a preliminary field test with several hundred striped bass in 1948. Soft-temper Monel metal wire, 0.036 inch in diameter, was used. A parallel aquarium test was carried on with 20 fish of the same species in a salt water tank at Steinhart Aquarium. All 20 of the wires used in this latter experiment had corroded sufficiently to cause loss of the tags after only six months. A photograph of a typical wire is shown in Figure 143I.

This experiment was subsequently repeated with another 20 Monel wires, using 10 from the same coil and 10 from a different batch of metal. The results were essentially the same. None of the tags stayed on longer than seven months, and corrosion was responsible for their loss. Moreover, Monel metal strap tags placed on the opercles of eight of these same fish also corroded rapidly.

These developments were baffling in view of the success experienced by the International Fisheries Commission, already mentioned. Differences in environmental conditions, in the fish themselves, or in the alloys used could explain the discrepancy.

At first it was believed that some peculiar electrolytic or chemical condition in the aquarium had produced a greatly increased rate of corrosion of the Monel metal wires over that which would have occurred in the ocean. However, the subsequent return of one of these same wires corroded almost to the breaking point after exactly one year on a wild striped bass suggested that essentially the same thing was happening in the ocean where it would, of course, be somewhat retarded, since in California these fish ordinarily move into fresh water during the winter. A photograph of a corroded Monel metal wire after 228 days on a wild striped bass is shown in Figure 143H. It is now obvious, on the basis of the aquarium experiments and additional corroded returns from wild fish, that Monel metal is also unsuitable for use in tagging salt-water fishes. Much better materials are available for the purpose.

Silver

Silver was turned to as one of the possibilities worth investigating after nickel and Monel metal were found wanting. Several hundred striped bass were tagged with disk tags and cold-rolled silver wire (0.036 inch in diameter) in a preliminary field test in 1950. A sizable number has already been returned, none corroded. However, this metal has proved to be unsuitable, because of its physical characters. The continual working which it undergoes on a strong and active fish, such as a striped bass, soon produces a sharply localized hour-glass type of attentuation. Returned wires have characteristically shown this, and have frequently been on the point of breaking after being out less than nine months. It is readily possible to reproduce this in a piece of silver wire by working it a few times with the fingers. This was done to produce the

TABLE 3

Corrosion of Nickel Pins on Bottom Fishes

Species of fish	Degree of corrosion of nickel pins	Days out					Total examined
		0-99	100-199	200-299	300-399	400-499	
English Sole *Parophrys vetulus*	None	1	4	12	8	4	39
	Corroded but not seriously weakened				1	2	
	Seriously weakened by corrosion				5	2	
Dover Sole *Microstomus pacificus*	None		1	9	1	2	16
	Corroded but not seriously weakened				1		
	Seriously weakened by corrosion				2		
Petrale Sole *Eopsetta jordani*	None			1			5
	Corroded but not seriously weakened						
	Seriously weakened by corrosion			2	2		
Sand Sole *Psettichthys melanostictus*	None						1
	Corroded but not seriously weakened						
	Seriously weakened by corrosion			1			
Starry Flounder *Platichthys stellatus*	None	1	5			2	8
	Corroded but not seriously weakened						
	Seriously weakened by corrosion						
Sablefish *Anoplopoma fimbria*	None	1					1
	Corroded but not seriously weakened						
	Seriously weakened by corrosion						
Curlfin Turbot *Pleuronichthys decurrens*	None		1	1			3
	Corroded but not seriously weakened						
	Seriously weakened by corrosion			1			
White Sturgeon *Acipenser transmontanus*	None			1			1
	Corroded but not seriously weakened						
	Seriously weakened by corrosion						

Green Sturgeon *Acipenser medirostris*	None						1
	Corroded but not seriously weakened						
	Seriously weakened by corrosion		1				
Combined Species	None	3	11	24	9	8	75
	Corroded but not seriously weakened				2	2	
	Seriously weakened by corrosion		1	4	9	2	
Total Examined		3	12	28	20	12	75
Percentage showing any corrosion		0	8.3	14.3	55	33.3	26.7

A corroded pin from a soupfin shark (*Galeorhinus zyopterus*) was observed before the start of this work. Unfortunately, the remainder of our few returned soupfin pins were not saved for a critical examination.

example shown in Figure 143G which is essentially similar in appearance to many of those actually returned from fish.

Silver is clearly not the answer to the problem and testing has been discontinued.

Stainless Steel

This was another of the metals given serious consideration when nickel and Monel metal proved unsatisfactory. It appeared promising in the light of information supplied by Scandinavian fisheries workers,[1] although local metallurgists who were consulted feared that, being an alloy, it might behave in the same way as Monel metal.

Active testing of stainless steel is now under way. Results to date are highly promising, but it is still too early for final conclusions.

Ten stainless steel wires, type 302,[2] diameter 0.032 inch, were tested on striped bass in a salt-water aquarium tank. None showed evidence of corrosion after seven months. After 13 months, three of the 10 tags remained in place, and the wires showed no evidence of corrosion. The actual record is better than this might indicate, for three tags had been removed for examination, three were shed or lost through the death of the fish, and one was lost when a plastic disk (Vinylite) cracked and fell off. None of these seven showed any signs of corrosion. After 19 months the two remaining wires similarly were uncorroded. All of these stainless steel wires were located on the caudal peduncle. It will be recalled that this was also the case with the nickel wires which failed to corrode.

In a second aquarium experiment, still in progress, the same type and diameter stainless steel wire from another source was tested in a similar manner. After nine months, 11 of the original 12 were still in place, and a careful examination revealed no evidence of corrosion. However, there was characteristically about one-fourth inch of slack. These tags were all located beneath either the first or second dorsal.

It is also too early for final conclusions from field tests on stainless steel in California, but the available evidence is favorable. Examination of a small number of returns of type 302 stainless steel wires from salmon and striped bass has revealed no corrosion, but none had been out more than eight months.

It is interesting to note that Cable (1950) reports success with stainless steel rivets and plastic disks on shad (*Alosa*).

Stainless steel wire has certain physical characteristics which are distinct disadvantages:

It is difficult to twist properly when locking the second tag disk in place. Even "dead soft" wire refuses to twist into a neat, compact "knot." To a person casually handling such wire, it seems much more flexible than (for example) our nickel pins, but the nickel will readily twist into a short radius curve and make a compact knot. The stainless steel will not, and efforts to make it do so are apt to injure the fish. The diameter of the wire has a great influence on this lack of short radius flexibility. Some 0.036-inch-diameter wire proved to be entirely useless

[1] The information was obtained by correspondence with Messrs. Einar Lea, Bergen, Norway, and Ph. Wolf, Malmö, Sweden.

[2] Composition of type 302 stainless steel, as defined by the American Iron and Steel Institute, is as follows: carbon 0.08-0.20 percent, manganese 2.0 percent maximum, silicon 1.0 percent maximum, phosphorus 0.04 percent maximum, sulphur 0.03 percent maximum, chrominum 17.0-19.0 percent, nickel 8.0-10.0 percent, remainder "iron."

for tagging. The 0.032-inch wire of the same temper was much better and has been used for all of our aquarium and field work.

A second difficulty has to do with the tags developing slack while on the fish. This appears to be partly due to the wire working its way through the flesh of the fish and partly to the tag disks pulling a little extra slack out of the loose knots described in the preceding paragraph. In our aquarium experiments, stainless steel tags had an average of a little over one-fourth inch of slack after nine months. At best, Petersen disk tags are overly susceptible to catching in nets and a slack tag with a poor knot is worse than average.

Stainless steel pins should be an improvement over wire in that they would have a knot on one end only. We have contacted 17 pin manufacturers to date and none was willing to make pins out of this material.

One final inconvenience of stainless steel is quickly discovered by every tagger. When this wire is cut with a pair of pliers, it takes on a razor-sharp tip that will slice into any flesh it touches.

Tantalum

Tantalum is a comparatively rare metal. We have not yet had time to test it thoroughly, but to date the only apparent disadvantage is its cost (about 15 cents for a wire 0.032 inch by three inches—enough for one tag).

This metal is used in human surgery because it is chemically inert, does not corrode, and is nontoxic. Tantalum wire possesses about the right degree of stiffness for tagging, and it is easy to twist into a good knot.

There was no evidence of corrosion on any of 15 tantalum wires used with disk tags on striped bass in Steinhart Aquarium. These tags had been in place for nine months when last examined. There seems to be little tendency for tantalum wires to develop slack.

It was reported to us that in human surgery flesh will attach to tantalum. A careful check was made in the aquarium tests to note if the fish flesh attached to the wires. In no instance was there any indication that this was happening with tantalum or any other metal.

Field tests with tantalum have been very limited. The few returns we have examined show no corrosion.

Plastics

A fairly intensive search has failed to uncover any nonmetallic filaments promising enough to warrant testing with Petersen disks. Fiberglass cuts itself when knotted and subjected to continual working. A great variety of plastic monofilaments which have been examined are unsuitable because they cannot be knotted satisfactorily in the required diameter. However, the search is being continued.

SUMMARY

Failure of the plastic materials used for Petersen-type disk tags by the California Division of Fish and Game has presented serious problems. Cellulose nitrate has been the most satisfactory, although it has tended to become brittle after prolonged storage. Thin cellulose acetate disks (0.030 inch) seemed satisfactory on flatfish, but have failed badly on salmon; thicker ones (0.045 inch) have stood up fairly well. Vinylite disks have been unduly brittle and subject to cracking.

Corrosion of metal wires used with these disks has been an even more serious problem. Nickel and Monel metal have proved entirely unsatisfactory because of their rapid corrosion on salt-water fish. Silver has been unsatisfactory because the wire soon broke. Stainless steel and tantalum are both highly promising on the basis of preliminary observations, and they are currently being tested further.

REFERENCES

Cable, Louella E.
1950. A cheek tag for marking fish, with semi-automatic pliers for application of tag. Cons. Per. Inter. Explor. Mer, Journ. du Cons., vol. 16, no. 2, p. 185-191.

Merriman, Daniel
1941. Studies on the striped bass (*Roccus saxatilis*) of the Atlantic Coast. U. S. Fish and Wildlife Service, Fishery Bulletin, vol. 50, no. 35, p. 1-77.

Thompson, William F. and William C. Herrington
1930. Life history of the Pacific halibut. (1) Marking experiments. International Fisheries Comm., Rept. no. 2, 137 p.

THE RELATIVE ABUNDANCE OF SHARKS AND BAT STINGRAYS IN SAN FRANCISCO BAY[1]

By Earl S. Herald
Steinhart Aquarium, California Academy of Sciences, San Francisco
and Wm. Ellis Ripley
Bureau of Marine Fisheries, California Division of Fish and Game

Through the studies of the California Division of Fish and Game as well as the catch records of the annual Coyote Point shark derbies, much information has accumulated on the shark and bat stingray populations in the central and southern portions of San Francisco Bay. These data, presented herein, should be considered as a preliminary working basis for future population studies in the Bay area. Most valuable was the information obtained from the catches of the Fourth Annual Coyote Point Shark Derby held on Sunday, September 17, 1950. The shark derby is an event held annually since 1947 and sponsored jointly by the San Mateo Lions Club and the Coyote Point Yacht Club. Through these sponsoring organizations many prizes are offered each year by local business men. The awards are made for a wide variety of catches such as the largest sharks, smallest shark, largest stingrays, with special awards for the best father and son team, best fisherwoman, best fishergirl, etc. This has stimulated a great amount of interest as indicated by the large number of fishermen registered for the yearly derbies. During the 1950 derby all of the fishermen obtained their catches within the area bounded by Hunter Point on the north, the east side of the channel in the center of the bay, and the shell mounds about one mile south of San Mateo Bridge (Figure 144). The majority of the boats fished within one and one-half miles of Coyote Point. There were no boats fishing on the east side of the bay although there are good shark fishing localities within that area.

The 1,406 fishermen registered with the 1950 derby officials turned in a total of 926 sharks and 89 bat stingrays (total weight 4,216 pounds).[2] This count was made by the senior author and Mr. Donald Simpson at the Royal Tallow and Soap Company on the morning after the derby. It is known that a number of sharks and bat stingrays were not turned in and hence not counted, but we have no way of estimating the exact number. Two rarities were among the catches, i.e., a thresher shark and a sixgill shark.

The catch data for each species taken during the 1950 shark derby (September 17) are presented in Table 1 together with a comparison of the June, 1948, derby catches as well as those made by the Division of Fish and Game during October and November of 1943. Data on the

[1] Submitted for publication December, 1950.

[2] Weight does not include 35 soupfin removed from contestants' boats which are included in the total count. Soupfin are protected in California and may be caught only in areas in which the depth is 25 fathoms or greater; specific gear is required. Soupfin may not be caught in San Francisco Bay.

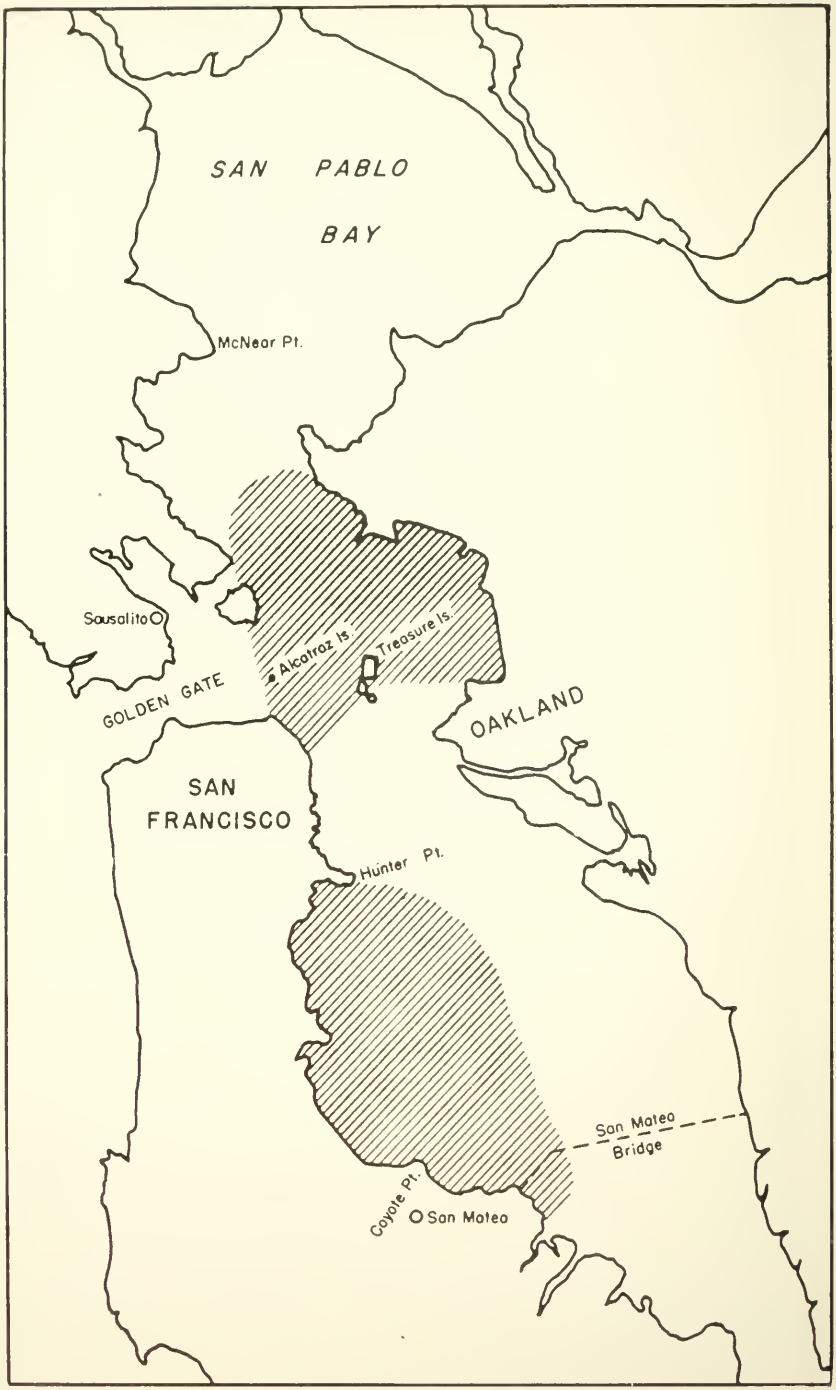


FIGURE 144. Map of San Francisco Bay showing fishing areas

TABLE 1

Data on Sharks and Bat Stingrays Caught in San Francisco Bay

Species	Number caught					Percentage caught				
	California Fish and Game, 1943 San Francisco Bay			Shark derbies		California Fish and Game, 1943 San Francisco Bay			Shark derbies	
	North Bay	South Bay	Total	1948	1950	North Bay	South Bay	Total	1948	1950
Brown smoothhound	488	661	1,149	54	539	78.7	48.2	57.7	43.9	58.2
Leopard shark	94	180	274	57	261	15.2	13.1	13.8	46.3	28.2
Dogfish	30	437	467	0	5	4.8	31.9	23.5	0.0	0.5
Soupfin	8	56	64	0	60	1.3	4.1	3.2	0.0	6.5
Sevengill shark	0	36	36	12	59	0.0	2.6	1.8	9.8	6.4
Sixgill shark	0	0	0	0	1	0.0	0.0	0.0	0.0	0.0
Thresher	0	0	0	0	1	0.0	0.0	0.0	0.0	0.0
Total sharks	620	1,370	1,990	123	926	100.0	99.9	100.0	100.0	99.8
Bat stingray	34	28	62	6	89					
Total sharks and bat stingrays	654	1,398	2,052	129	1,015					
Percentage of bat stingrays in total shark and bat stingray catch						5.2	2.0	3.0	4.6	8.8

TABLE 2

Set Line Catch in the Northern Part of San Francisco Bay

October-November, 1943 [1]

Station	Hooks used	Minutes fished	Hook-minutes	Catch							
				Brown smooth-hound	Leopard shark	Dogfish	Soupfin	Sevengill shark	Bat stingray	Skate	Total catch per set
3	111	30	3,330	20	1	0	4	0	11	1	37
4	111	40	4,440	27	1	0	0	0	6	1	35
5	111	30	3,330	34	2	1	1	0	4	0	42
7	220	25	5,500	40	3	0	0	0	0	0	43
8	220	40	8,800	29	4	1	0	0	4	0	38
9	110	25	2,750	4	1	0	0	0	0	0	5
10	330	25	8,250	22	4	1	0	0	3	3	33
11	272	41	11,152	35	12	2	0	0	0	0	49
12	272	22	5,984	24	16	4	0	0	0	0	44
18	220	50	11,000	22	0	0	0	0	1	0	23
19	220	30	6,600	1	1	0	0	0	0	0	2
23	555	25	13,875	129	45	16	0	0	2	4	196
Totals	2,752	383	85,011	387	90	25	5	0	31	9	547

[1] Two stations are not included: Station 2, 39-hook set line and three hand lines, and Station 17, 162-hook set line.

TABLE 3

Set Line Catch in the Southern Part of San Francisco Bay

October-November, 1943 [1]

Station	Hooks used	Minutes fished	Hook-minutes	Catch							
				Brown smooth-hound	Leopard shark	Dogfish	Soupfin	Sevengill shark	Bat stingray	Skate	Total catch per set
13	550	30	16,500	130	70	22	0	1	0	0	223
14	162	25	4,050	7	4	5	0	0	2	0	18
15	220	35	7,700	45	4	22	2	2	1	0	76
16	440	20	8,800	90	33	18	0	0	5	4	150
20	275	10	2,750	34	1	39	4	0	0	0	78
21	275	47	12,925	60	7	72	0	0	2	0	141
22	220	15	3,300	23	1	63	3	0	0	0	90
24	440	25	11,000	64	12	48	7	1	2	1	135
25	220	26	5,720	56	3	36	7	2	1	0	105
26	880	33	29,040	128	9	110	32	1	11	1	322
Totals	3,682	266	101,785	637	141	465	55	7	24	6	1338

[1] Two stations are not included: Station 1, trammel net, and Station 6, five hand lines.

1948 derby catches were taken by the junior author. In addition, the 1943 shark studies were under his direction.

The 1943 fishing was divided between two separate areas in the bay (the shaded portions of Figure 144), the southernmost of which corresponds approximately to that area fished during the annual shark derbies. Since the 1943 fishing was carried out during October and November and that of the 1950 derby during September, these data are more comparable than that of the June, 1948, derby.

To compare accurately the relative abundance of the sharks of the northern part of the bay with those of the southern section, all data from the 1943 survey were summarized. Only those data which were comparable (set line-caught sharks) were considered. Sharks not included in the calculations were those taken by trammel net (Station 1, south bay) and by hand lines (Station 6, south bay, and Station 2, north bay), as well as those taken by one set line with inadequate data (Station 17, north bay). From Tables 2 and 3 it will be noted that the total set of hooks per station ranged between 110 and 880. These tables also present other essential data, i.e., fishing time and resultant catch by species. Total hook minutes were obtained for each set of gear by multiplying the time fished by the number of hooks used. Combining the records for all stations, the number of hook minutes was divided into the number of sharks caught. Division by 60 and multiplication by 100 resulted in a figure giving the average number of sharks taken per 100 hook-hours of fishing time. This same method was applied to obtain the catch by species per 100 hook-hours. The data are presented in Table 4.

TABLE 4

Number of Sharks Caught Per 100 Hook-Hours of Fishing Time
San Francisco Bay: October-November, 1943

Species	North Bay	South Bay	Species	North Bay	South Bay
Brown Smoothhound	27.31	37.55	Soupfin	0.35	3.24
Leopard Shark	6.35	8.49	Sevengill Shark		0.41
Dogfish	1.76	27.41	All sharks combined	35.78	77.10

From this table the brown smoothhounds are found to be the most abundant species in both sections of the bay. In the northern section the order of abundance is brown smoothhound, leopard shark, dogfish, and soupfin. In the southern section it is brown smoothhound, dogfish, leopard shark, soupfin and sevengill shark. There were none of the latter species in the northern section. Table 4 also demonstrates that the south bay is more than twice as productive as the north bay in terms of all sharks caught (77.10 sharks per 100 hook hours as compared with 35.78).

To compare all of the data from the various shark derbies with that of the 1943 survey, it was necessary to use a percentage treatment as the methods of fishing were too varied to permit application of a standardized unit of effort. Discussion of the south bay Fish and Game catches (1943), as compared with the 1948 and 1950 shark derbies, will be made under the individual species. It is cautioned that sharp fluctuations in abundance for any species from one series of data to the next may result in a percentage difference in other species, as previously indicated, which

will be more apparent than real. For example, the drop in the percentage catch of dogfish between 1943 and 1950 (from 31.9 to 0.5 percent) would necessarily cause the difference between these two figures to be reflected as an apparent but not real increase in other species of the 1950 catch.

BROWN SMOOTHHOUND, *TRIAKIS HENLEI*

Table 1 indicates a general agreement in the percentage catch of brown smoothhounds, i.e., 48.2 percent of the south bay shark catch in 1943, 43.9 percent in 1948 and 58 percent in 1950.

Based on an examination of stomach contents, the brown smoothhound appears to feed in the bay by preference upon small crabs and shrimp. In the Aquarium brown smoothhounds must be handled with care for they are usually difficult to keep in good health. At night a lighted bulb must always be in place over the tank, otherwise the smoothhounds bump into the side walls so often that within one or two weeks the noses are badly abraded and death results. Gravid females will occasionally drop their young in the aquarium tanks.

LEOPARD SHARK, *TRIAKIS SEMIFASCIATA*

Data on the percentage catches for this species are rather erratic although the northern and southern areas are in agreement (15.2 versus 13.1 percent for 1943). In 1948 the percentage catch jumped to 46.3 percent and in 1950 dropped to 28.2 percent.

The leopard is one of California's toughest sharks. It can be kept out of water for a considerable time and will revive when again placed in water. It lives for several years in the Aquarium and adapts itself readily to any type of food. Males have been recorded as reaching a maximum length of 3 feet (Roedel and Ripley, 1950, p. 51). Among the shark derby catches were two males of approximately 4½ feet.

DOGFISH, *SQUALUS ACANTHIAS*

In the southern section of the bay the dogfish is usually the second most abundant shark. Consequently, the scarcity of specimens in the catch of the 1950 shark derby was a source of considerable interest. Only five dogfish were taken, four adults and one juvenile. The senior author helped to weigh the sharks taken during the 1949 derby, and although no count was made at that time, it is estimated that there were at least 35 or 40 of this species. The 1943 (October-November) figures indicate that the dogfish furnished 31.9 percent of the sharks caught in the southern part of the bay. Yet in September, 1950, the same area yielded only one-half percent of this species in the total catch.

Foerster (1942) has reported the preliminary results of dogfish tagging in the British Columbia area. During 1941, 564 dogfish were tagged in four different groups. From these releases there were 34 recoveries. Although the returns indicated much movement during the period of freedom, it was not possible to demonstrate a migration pattern. There are three records of tagged dogfish moving from Washington to Oregon and California for a maximum distance of 760 miles during a period of 6 to 18 months (Bonham et al., 1949, p. 92). According to Bigelow and Schroeder (1948, p. 455) the same species of dogfish occurs on

the Atlantic Coast. In that area there is not only much variation in seasonal abundance, but also a good deal of sudden and erratic local movement from locality to locality. Thus it seems that there is a probability that the Pacific Coast dogfish population may fluctuate in a manner similar to that of the population on the Atlantic Coast. Such might explain the absence of dogfish from the 1950 derby catches.

One other possible factor in the disappearance of the dogfish from the southern end of the bay should be discussed. Beginning about 1945 there was an extensive trawl fishery for dogfish developed in Northern California waters during the months of October through January. It is possible that this concentrated fishing effort might have reduced the dogfish broodstock population.

In an effort to check on the significance of the absence of dogfish from the derby catches, the senior writer visited the Hunter Point Shrimp Company on September 28, 29, and 30, which was 11 to 13 days after the derby. The nets operated by this company fish on the bottom from fixed positions about two miles south of Treasure Island. During the three days there were 61 sharks caught, including 30 dogfish, 20 brown smoothhounds, one leopard and one thresher. This was not as many as would normally be expected; but, as pointed out by the fishermen, the presence of considerable seaweed drives fishes and sharks away from the nets. These inadequate catch figures show that dogfish composed about 49.2 percent of the shark catch. Since these data were not obtained at the same time as the shark derby, their significance is somewhat decreased. However it does seem that the absence of dogfish from the 1950 catches could most probably have been caused by one of the sudden erratic local movements described by Bigelow and Schroeder (1948, p. 460).

We have not been too successful in keeping dogfish in the Aquarium for any extended period of time. Without a nightlight over the tank this species, like the brown smoothhound, quickly wears off its nose on the walls. Mr. W. E. Sullivan of the Depoe Bay Aquarium (Oregon) advises us that they are able to keep dogfish alive for a maximum time of about one month. At Steinhart Aquarium we have had one clutch of four young which were dropped by a 102-cm. (40-inch) female (October 15, 1950). The young survived only about two days and the pangs of sharkbirth were apparently too much for the mother as four days later she died.

The dogfish is an extremely wide-ranging species, occurring not only on both sides of the North Pacific but also on both sides of the North Atlantic.

SOUPFIN SHARK, *GALEORHINUS ZYOPTERUS*

Despite the restriction on the taking of soupfin shark, at least 60 were caught at the derby. The senior author counted 14. The junior author tagged and released 11 that had been caught by contestants. Warden E. M. McLaurin, aboard the patrol boat "Minnow," recovered 35 dead soupfin from other fishing boats. This is a total of 60 which is considerably in excess of the approximate dozen specimens observed by the senior author during the 1949 derby. This small increase may be due in part to the legal protection which has been given to the soupfin as well

TABLE 5

Recoveries of Tagged Soupfin

The last two fish were marked under the direction of the Oregon Fish Commission. Data are from Westrheim (1950)

Original data						Recovery data					
Date tagged	Tag number	Sex	Weight, length	Tagged by	Where tagged	Date recovered	Elapsed time	Approximate distance	Weight length increase	Recovered at	Recovered by
July 18, 1943	A-3272	female	43 in. T.L.	Calif. Div. Fish and Game	16 mi. S. of Ventura, Calif.	Sept. 11, 1945	2 years $1\frac{3}{4}$ months	1000 mi. northward		Neotka Sound in Bajo Reef, Vancouver, British Columbia	M.G. Johnson
Jan. 20, 1949	8728	male	54 in. T.L.	Lloyd Lindwall, Santa Barbara	10 mi. NW San Martin Id., Baja Calif.	July 5, 1949	$5\frac{1}{2}$ months	190 mi. northward		Solana Beach near San Diego 500 ft. depth	Vernon Dodson
						5 lb. sal mon in stomach					
May 18, 1949	8749	female	55 in. T.L.	Warren Beadle, Venice, Calif.	5 mi. S. of Pt. Mugu, Calif. 60 fathoms	Aug. 29, 1949	$3\frac{1}{6}$ months	1100 mi. northward	2 in.	Hecate Strait, British Columbia	Fred Sandness, Astoria, Oregon
May 23, 1949	8753	female	38 in. T.L.	Warren Beadle, Venice, Calif.	Off Malibu Pt., Calif. 53 fathoms	May 27, 1949	4 days	95 mi. southward		$2\frac{1}{2}$ mi. off San Marcus Creek, Encinitas, Calif.	Unknown
May 7, 1949		male	19 lbs. 51 in. T.L.	Oregon Fisherman	50 mi. W. Pt. Sur, Calif.	Aug. 28, 1949	$2\frac{2}{3}$ months	90 mi. northward	4 in.	Halfmoon Bay, Calif.	Unknown
Aug. 5, 1949		male	56 in. T.L.	Oregon Fisherman	WNW of Cape Scott Vancouver Id., British Columbia	Aug. 7, 1949	2 days	75 mi. eastward		SE corner Queen Charlotte Sound, British Columbia	Unknown

as to the almost complete cessation of commercial fishing activities during 1950. The soupfin has been twofold cursed by the possession of a delicious dorsal fin as well as a vitamin-rich liver.

Fishermen report that before the war large numbers of both sexes of soupfin were present in the bay. In the early part of the war the bay was closed to set line fishing thus providing some protection. However in adjacent localities many soupfin were caught, resulting in an over-all reduction in abundance. The studies made by the junior author (1946) have shown that the females move into the bay to drop their young. Whether these brood females are resident in the San Francisco region is not known. The junior author has also shown that the soupfin population in Northern California is composed mostly of males, in Southern California mostly of females and in Central California of an approximate 50 50 ratio. With this peculiar distributional pattern there must be considerable migration. There have been 118 soupfin tagged in the State by interested California fishermen as well as by the Division of Fish and Game. From these tagged soupfin there have been only four returns, the data for which appear in Table 5. Number 8753 is probably the most interesting record, for this female traveled about 95 miles southward in the short time of four days. Another female, No. 8749, was tagged five days later and 30 miles northward of the point where 8753 was tagged. Despite this short time and distance separating the tagging areas, No. 8749 traveled in the opposite direction, i.e., northward for approximately 1,100 miles to Hecate Strait, British Columbia, during a period of $3\frac{1}{2}$ months. Number A-3272 (female) was tagged 15 miles north of 8749 and also migrated northward for more than 1,000 miles to the vicinity of Vancouver, British Columbia, during the next $2\frac{1}{2}$ years; this specimen has been previously reported by Ripley (1946b). Number 8728 (male) moved about 190 miles northward during $5\frac{1}{2}$ months of freedom between tagging and recapture. The five-pound salmon in the stomach of this specimen is noteworthy since it is only rarely that salmon are taken in the San Diego area.

Westrheim (1950) reported 18 soupfin tagged by Oregon fishermen during 1948 and 291 during 1949. Of the 1949 group 85 were tagged in the area between Point Conception and Eureka. There were two recoveries during 1949 (Table 5). A male tagged at Point Sur moved about 90 miles northward during $2\frac{2}{3}$ months of freedom and grew four inches in length during that time. Another male, tagged near Cape Scott, Vancouver Island, British Columbia, traveled 75 miles eastward during two days of freedom.

No conclusions can be drawn from this small amount of data. However, it is of interest to note that two of the three females migrated for more than 1,000 miles and that the third female averaged about $27\frac{1}{2}$ miles per day for four days. One male moved a total of 190 miles in $5\frac{1}{2}$ months. Another male moved 90 miles in $2\frac{2}{3}$ months and the third male, 75 miles in two days.

For the 1950 derby the Division of Fish and Game prepared a mimeographed sheet for distribution to all fishermen. This paper presented graphically the principal characters used to distinguish the various species of sharks, including the soupfin. In all press releases by the sponsoring organizations the restrictions on the taking of soupfin were

fully discussed. Despite these precautions the 60 specimens mentioned above were caught and most of them not released.

Several attempts have been made to bring living soupfin to the Aquarium but all have met with failure. Consequently we have no knowledge of the manner in which this species acts in captivity.

SEVENGILL SHARK, *NOTORYNCHUS MACULATUM*

The 59 sevengill sharks caught during the derby represent an apparent 2½ percent increase over the 1943 records. In this latter year 36 specimens were caught of which 25 were females and 11 were males. However, of the 33 specimens sexed at the 1950 derby the reverse was true, for 22 were males and 11 were females.

Internal examinations were made on 37 specimens. Only three fish had food in the stomach other than bait. One fish contained four separate pieces of sardine bait. None of the fish was sexually mature. A 16¼ pound male had a gonad which weighed only 4.5 grams whereas a female of 20½ pounds had an equally small gonad of 5.2 grams. It is often possible to explain the marked predominance of one sex in a given population on the basis of migration and movements connected with sexual maturity and reproduction. However, such explanation will not clarify the apparent reversal in the numbers of each sex shown by comparison between the 1943 and 1950 catches. We are at a loss to explain this reversal except by the smallness of the sample.

In all of the four shark derbies held to date the largest sharks caught have been sevengills. In order of size they have been 36 pounds (1948), 34 pounds (1949), 30 pounds (1947) and 27½ pounds (1950). The 1943 Fish and Game records list three specimens larger than this, i.e., one shark of 42 pounds, another of 50 pounds and the largest, 106½ pounds. It is probable that the majority of sevengills leave the bay by the time they have attained a weight of 50 pounds (Figure 145).

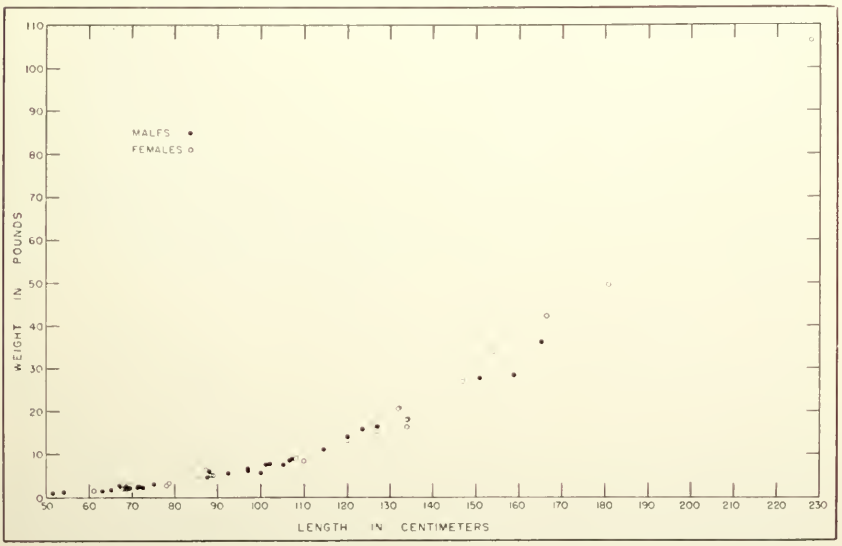


FIGURE 145. Length-weight graph for 61 young sevengill sharks caught in San Francisco Bay

Since this species is ovoviviparous, bearing its young alive, it is interesting to speculate as to the manner in which the young arrive in the bay. Do the adult females enter the bay and drop their young, or are they dropped outside of the bay and subsequently carried in by the currents as well as by the juveniles' own swimming ability?

Although we have no knowledge of the occurrence within the bay of the large adult sevengills (maximum length 15 feet), nevertheless there is evidence of the presence of large shark-like animals in the area. On November 1, 1943, the junior author made a set of 162 hooks between Alcatraz and Treasure Islands. Each end of the set was weighted with a 25-pound anchor and one end carried a buoy line. During this operation some large fishlike organism cut the gear in half and dragged the remainder out towards the Golden Gate where it was lost. Since a submarine net was in operation at the time, the probability of this having been caused by a whale or blackfish is limited as animals of this diameter would not have been able to penetrate the net and, in any event, they do not take bait. The writers hold the unproved conviction that the culprit might have been a large sevengill shark.

A swimming sevengill shark is a beautiful sight to behold, and in the Aquarium it never seems to stop swimming. Day or night, the sevengill is usually on the move. This swimming habit is undoubtedly correlated with the fact that the adults are open-water sharks not limited to inshore coastal areas. A young sevengill shark caught September 17, 1950, lived in the Aquarium until January 17, 1951, when it died as the result of an accident. During these four months the shark was never observed to rest on the bottom, and it never learned to feed itself in captivity. It was force-fed usually three times a week being given one-half a sardine or the equivalent at each feeding.

In the bay there seems to be an indication that the sevengill prefers the deeper water. At the 1950 derby many catches of brown smoothhounds, leopard sharks and bat stingrays were made in water of 8 to 15 feet depth. However, most of the sevengills came from water deeper than 20 feet. The preferred area near Coyote Point seemed to be the section along the edge of the dropoff into the deeper portions of the main channel. During the 1943 Fish and Game survey the best catches of sevengill sharks were made in an area about two miles southeast of Hunter Point at a depth of 30 to 35 feet. During 6½ hours of fishing (10.15 a.m. to 4.45 p.m.) three persons using five handlines and sardine bait caught 605 pounds of sevengill sharks (17 males and 21 females) including one female of 106½ pounds. In addition there were caught 216 pounds of leopards and 136 pounds of brown smoothhounds.

A sevengill shark just pulled out of the water is a nasty fish to handle. In a small boat it is often imperative to kill it immediately, for otherwise the belligerent disposition of the shark as well as its tendency to use its jaws and sharp teeth on anything in the vicinity makes it a dangerous liability. Recently an Aquarium staff member was force-feeding the small sevengill shark previously mentioned, and being accustomed to shoving sardines down the throats of other types of sharks with his fingers, he applied the same method to the sevengill. When he finished the feeding, he was surprised to find a deep and subsequently painful gash on one of his fingers. Needless to say, this technique has now been modified.

Since little information is available on sevengill sharks, there are presented in Figure 145 the weight-length data for 61 of the specimens examined.

SIXGILL SHARK, *HEXANCHUS GRISEUS*

One of the two rarities taken during the derby fishing was a young female sixgill shark with a weight of 20¼ pounds and a length of 1290 mm. (50⅘ inches). It was caught by Mr. Jack Morris of San Francisco at a location in the channel one-half way between Hunter Point and Coyote Point. The catch was made in 35 feet of water with sardine bait. There is a single published record for San Francisco Bay; Evermann (1929, p. 348) listed "two fishes (*Hexanchus corinus*) from Sausalito, California." These were caught at Peterson's Boat House on July 14, 1928, and presented to the Academy by the fisherman (Cat. No. 2183). On March 19, 1945, Mr. Donald Simpson, Aquatic Collector for Steinhart Aquarium, caught a 670 mm. (26⅖ inches) male sixgill shark at the intake of the Pacific Gas and Electric plant in San Francisco (CAS Cat. No. 11615). To our knowledge the largest shark ever caught in San Francisco Bay was a 464 pound sixgill. This 11-foot specimen was taken during July, 1928, by Mr. R. C. Pell of San Francisco (Figure 146). The catch was

FIGURE 146. The largest shark known from San Francisco Bay—a sixgill caught near Sausalito by Mr. R. C. Pell, July, 1928 (11 feet and 464 pounds)

made at Yellow Bluff which is about one-half mile inside of Golden Gate Bridge near Sausalito.

The recorded range on the Pacific Coast for the sixgill shark is from northern British Columbia to Southern California (Roedel and Ripley, 1950, p. 40). In addition to the Pacific Coast the sixgill shark has an extremely wide range, being known from both sides of the Atlantic, the Mediterranean and South Africa as well as from Chile, Japan, Australia

and the southern Indian Ocean. The most complete discussion of the species is to be found in Bigelow and Schroeder (1948, p. 80). These authors give the maximum length of the sixgill shark as 26 feet with most large adults attaining a maximum length no greater than 15½ feet.

THRESHER SHARK, *ALOPIAS VULPINUS*

The most spectacular catch of the 1950 derby was a young male thresher shark weighing 6¾ pounds and measuring 1168 mm. total length (46 inches). This shark was caught on sardine bait at a depth of 18 feet near the channel marker off Coyote Point by Mr. Raymond Farmer of Redwood City. Mr. Farmer tells of the thresher's rolling in the water several times after being hooked, in the same manner as is characteristic of some of the large striped bass. This specimen is now cataloged in the California Academy of Sciences Ichthyological Collections, No. 20438.

While visiting Hunter Point Shrimp Company docks on September 30, 1950, the senior writer was surprised to find a 37-pound female thresher shark among the few sharks taken on that day. This was the first shark of this kind which the fishermen had seen. The total length of the specimen was 1935 mm. (76⅕ inches) with the length to the notch in front of the tail 898 mm. (35⅜ inches). The stomach was crammed with 18 anchovies, and the ovaries were flattened showing no sign of maturity (144.5 grams). This specimen is now cataloged as CAS No. 20453.

There is a record of two threshers taken during 1947 in salmon gill nets fishing off McNear's Point in San Pablo Bay (Roedel and Ripley, 1950, p. 47). These "very long-tailed specimens" were taken by a chartered boat doing salmon tagging. The biologist in charge was not familiar with the local sharks but did observe the long tails, which were later cut off by the fishermen. Bigelow and Schroeder (1948, p. 168) report two small specimens from San Francisco in the collections of the Museum of Comparative Zoology. There is no information as to whether these were taken in the bay or were brought to San Francisco by boats fishing in other areas.

In California the thresher shark is not uncommon south of Santa Cruz; however, north of Santa Cruz very few are taken.

We have never had a thresher shark in the Aquarium so cannot report on its behavior in captivity. The thresher's long tail and fast swimming ability might pose serious problems if the shark were kept in a restricted area.

BAT STINGRAY, *HOLORHINUS CALIFORNICUS*

This large stingray is reported to attain a weight of 150 pounds (Roedel and Ripley, 1950, p. 78). Those which have been taken at the shark derbies have weighed considerably less than this maximum weight. In 1948, 1949 and 1950 the largest bat stingrays caught weighed 40, 58 and 45 pounds respectively. The species ranges along the Pacific Coast from Oregon to Magdalena Bay, Baja California. It occurs most commonly in shallow bays and sloughs.

The handling of large bat stingrays out of water is often a problem. If the specimen is not to be saved, then the quick removal of the tail including the dangerous spine is sufficient. However, if the bat stingray is to be used for exhibition in an aquarium, one needs two sturdy hands

and a pair of pliers. Two fingers of one hand are inserted, one in each spiracle; using the pliers in the other hand the tail is carefully seized at the spine, and the bat ray is carried to the nearest tank of water. Large bat rays of 30 or more pounds are usually sluggish in the Aquarium and often do not readily learn to avoid the sides of the tank. The resultant abrasion of the pectoral wing tips has caused the eventual death of some specimens. Young bat rays of 20 pounds and less seem to adapt themselves to tanks and various foods without difficulty.

As indicated in Table 1 the 89 bat stingrays caught during the 1950 derby represented a considerable increase proportionally over the 28 caught in the same area during the 1943 fishing. In the fishing area north of Treasure Island the percentage of bat stingrays in the total bat stingray and shark catch was intermediate between the 1943 and 1948 south bay catches, i.e., 5.2 versus 8.0 percent (1950) and 2.0 percent (1943).

Most of the bat stingray's tails from the 1950 derby were removed by Mr. Marvin Kolber, instructor at San Mateo Junior College, for the study by Dr. Bruce Halstead (1950) of the function of the spine and poison gland. This activity created much wild-eyed speculation among the many visitors at the derby as to the reasons for this procedure.

REFERENCES

Bigelow, Henry B., and William C. Schroeder
1948. Fishes of the western north Atlantic. Chap 3. Sharks. Sears Found. Marine Res., Memoir 1, pt. 1, p. 59-546, 101 figs.

Bonham, Kelshaw, and others.
1949. Biological and vitamin A studies of dogfish landed in the state of Washington (*Squalus sucklegi*). Washington Dept. Fish., Biological Rept. 49A, p. 83-114, 41 figs.

Evermann, Barton Warren
1929. Report of the director of the museum for the year 1928. Calif. Acad. Sci., Proc., vol. 17, 4th ser., p. 308-360.

Foerster, R. E.
1942. Dogfish tagging—preliminary results. Canada. Fisheries Res. Bd. Pacific Coast Sta., Progress Rept. no. 53, p. 12-13.

Halstead, Bruce W., and F. Rene Modglin
1950. A preliminary report on the venom apparatus of the bat-ray *Holorhinus californicus*. Copeia, no. 3, p. 165-175, 6 figs.

Ripley, Wm. Ellis
1946a. The soupfin shark and the fishery. Calif. Div. Fish and Game, Fish Bull. 64, p. 7-37, 18 figs., 12 tables.
1946b. Recovery of a tagged soupfin shark. Calif. Fish and Game, vol. 32, no. 2, p. 101-102.

Roedel, Phil M., and Wm. Ellis Ripley
1950. California sharks and rays. Calif. Div. Fish and Game, Fish Bull. 75, 88 p., 65 figs.

Westrheim, Sigurd J.
1950. The 1949 soupfin shark fishery of Oregon. Oregon Fish Comm., Research Briefs, vol. 3, no. 1, p. 39-49, 3 figs., 4 tables.

RESULTS OF THE PISMO CLAM CENSUSES, 1948, 1949, AND 1950[1]

By Robert D. Collyer
Bureau of Marine Fisheries, California Division of Fish and Game

Since 1925, the Bureau of Marine Fisheries has made a census of the Pismo clam (*Tivela stultorum*) population in the Pismo Beach area during the period of lowest tides each November. This report covers the censuses conducted in 1948, 1949, and 1950.

A trench or section is dug across the beach from the high tide mark as far out as it is possible to collect the clams. The section, standard each year, is 6 inches wide and $8\frac{3}{4}$ inches deep. For most of the length of the section, the sand is thrown to the side in such a manner as to spread it out in a thin layer. As long as the beach is just wet, and there is not too much water, this system works perfectly. Even the smallest clams are easily seen. When the trench reaches the point where too much surf prevents spreading of the sand, it is then passed through a screen of one-fourth-inch mesh. Eventually, too much water forces abandoning the screen. From then on probing is done, which turns out only the larger clams. Former studies have shown that over 90 percent of the young clams are found in the intertidal zone, which is more than covered by the throwing and screening methods. Thus only a very few of the clams would be missed in a section.

The locations of the sections are: (1) Pismo—one-eighth mile north of Pismo Pier, (2) Oceano—$1\frac{1}{16}$ miles south of Pismo Pier, (3) Le Grande—one mile south of the north boundary of the old clam refuge, (4) Morro—nine-tenths mile north of Morro Rock, (5) Cayucos—eight-tenths mile south of the Standard Oil Pier.

The first three sections are on Pismo Beach proper. The Oceano section is in a new clam refuge which was closed to digging by act of the Fish and Game Commission on November 5, 1949. The Le Grande section is in the old refuge which was closed from 1929 to 1949. The Pismo Section has always been open to clamming.

The two remaining sections lie to the north of Pismo Beach in an area between Morro Bay and Cayucos which is potentially good clam bearing beach. Sportsmen have planted clams in various places, supplementing the few already present, in the hope of building up future clamming along this stretch of the coast. At the time the Oceano preserve was established, another area which extends $1\frac{1}{2}$ miles north from Morro Rock, was also made a refuge. The portion of Cayucos beach between Big Creek and Old Creek was closed to digging by the Fish and Game Commission on September 29, 1950. Both the Morro and Cayucos preserves were established at the request of San Luis Obispo County sportsmen. The census sections are in these recently closed areas.

[1] Submitted for publication January, 1951.

Until 1949, the census was confined to Pismo Beach. In the 1948 census, only the Oceano section was dug. All five sections were dug in 1949 and all but the Pismo section in November, 1950.

The number of clams found are shown by age in Table 1 and by size in Table 2. Zero year clams are those spawned the year of the census. One-year clams are those spawned the year before and are approaching two years of age. Table 1 shows 22 zero group clams taken from the Morro and Cayucos sections in 1949. No one-year clams were found on these sections in 1950, indicating a total loss of what might have been a fair set of young clams.

The results of the clam censuses are perturbing. First, there has been an almost complete lack of young clams for the past three years. Second, there has been a reduction each year in the total number of clams found. The 1950 clam census showed the smallest clam population since 1941. The backlog of old clams in the former refuge (Le Grande) was reduced, in one season, to the point where diggers are now getting very few except those just reaching five inches, the minimum legal size. In

TABLE 1

Number of Clams by Age Groups

Pismo Beach

Age in years	1948	1949				1950		
	Oceano	Oceano	Le Grande	Pismo	Total	Oceano	Le Grande	Total
0			1		1			
1	39	3		4	7	1		1
2	97	33	14	6	53			
3	31	77	69	45	191	17	5	22
4	21	27	20	18	65	41	9	50
5	29	15	17	41	73	39	25	64
6	24	6	12	34	52	27	19	46
7	13	2	5	6	13	16	9	25
8+	5		15		15	13	7	20
Totals	259	163	153	154	470	154	74	228

Morro Bay—Cayucos Beaches

Age in years	1949			1950		
	Morro	Cayucos	Total	Morro	Cayucos	Total
0	3	19	22			
1						
2	7		7			
3	1	1	2			
4	1	1	2	2	1	3
5	33	8	41	2		2
6	31		31	6	1	7
7	1		1	7	1	8
8+				15		15
Totals	77	29	106	32	3	35

TABLE 2

Number of Clams by Size

Pismo Beach

Inches	1948	1949				1950		
	Oceano	Oceano	Le Grande	Pismo	Total	Oceano	Le Grande	Total
Under 1			1		1			
1–2	13	2		4	6	4		1
2–3	76	21	9	2	32	2	4	3
3–4	86	95	72	50	217	49	32	81
4–5	80	42	57	92	191	90	40	130
5–6	4	2	13	6	21	11	1	12
6+			1		1			
Totals	259	162[1]	153	154	469	153	74	227

Morro Bay—Cayucos Beaches

Inches	1949			1950		
	Morro	Cayucos	Total	Morro	Cayucos	Total
Under 1	3	18	21			
1–2						
2–3	1		1			
3–4	13	1	14	6		6
4–5	56	7	63	18	3	21
5–6	4	2	6	8		8
6+						
Totals	77	28[1]	105	32	3	35

[1] One clam injured and not measured.

1949, 13 days after the refuge was opened, the section yielded 14 legal sized clams. In 1950, the same section contained just one legal clam, and it was exactly five inches. In addition, the number of smaller clams in the Le Grande section in 1950 was approximately one-half that of 1949. Somewhat similar reductions in numbers occurred in the other sections. There can be little doubt that the present status of the Pismo clams on these beaches is bad. However, there is also reason to expect good sets of young clams in the next few years and that the clam population will be re-established, at least temporarily.

Legislation has gone about as far as possible toward protecting the Pismo clams, but there is considerable that individual diggers can do toward the preservation of this valuable mollusk and the fine recreation that is dependent upon its continued abundance. Undersized clams should be replaced in the sand close to where they were dug or if washed out by a storm, they should be returned to the water where they can survive. It is best to bury the clams just under the surface of the sand, with the hingelike ligament up and toward the sea.

REFERENCES

Aplin, J. A.
1947. Pismo clam increase. Calif. Fish and Game, vol. 33, no. 3, p. 129-131.

Fitch, John E.
1950. The Pismo clam. Calif. Fish and Game, vol. 36, no. 3, p. 285-312.

Herrington, William C.
1930. The Pismo clam, further studies of its life history and depletion. Calif. Div. Fish and Game, Fish Bull. 18, 69 p., 16 figs.

Weymouth, Frank W.
1923. The life history and growth of the Pismo clam. (*Tivela stultorum* Mawe). Calif. Fish and Game Comm., Fish Bull. 7, 120 p., 14 figs.

PSEUDOFINS ON THE CAUDAL PEDUNCLE OF JUVENILE SCOMBROIDS[1]

By Earl S. Herald
Steinhart Aquarium, California Academy of Sciences
San Francisco

While studying Philippine frigate mackerel (*Auxis thazard* and *Auxis tapeinosoma*) as a member of the Philippine Fishery Program of the U. S. Fish and Wildlife Service, the writer was surprised to find that two of the three solid ridges which are conspicuous along the side of the tail of adult *Auxis* actually develop as small, unstriated, finlike structures. At a later date through the courtesy of the Pacific Oceanic Fisheries Investigations of the Fish and Wildlife Service, the writer was enabled to examine a series of juvenile Costa Rican *Auxis*. The pseudofins along the caudal peduncle of these specimens proved to be similar in all respects to those of the Philippine material. Mr. John E. Fitch, of the California Division of Fish and Game, has told me that in nine small *Auxis* from the Mexican coast well-developed pseudofins were found in a 42 mm. specimen. Pseudofins were just forming in a 32 mm. specimen but were not discernible in the remaining seven which ranged from 13 to 27 mm.

The lateral ridges in which the fin rays develop may sometimes be discernible in fish as small as 20 mm. (standard length). In others they may not develop until the fish is nearly 30 mm. The greatest development of the pseudofins usually takes place when the fish is between 30 and 40 mm. By the time the fish has attained the latter length the pseudofins are invariably well developed (Figure 147).

[1] Submitted for publication December, 1950.

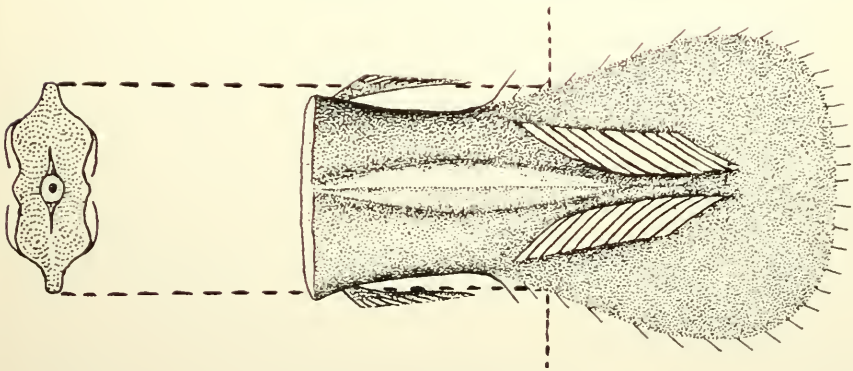


Figure 147. Lateral view of the caudal peduncle of a 42 mm. *Auxis thazard* from Menado, Celebes. Cross-sectional view at left. Pablo Bravo, del.

Under the microscope each *Auxis* pseudofin is usually found to consist of 11 unstriated soft rays. On some specimens as many as 14 rays have been counted. These structures probably have no outstanding anatomical significance and are undoubtedly similar to the ceratotrichia of other vertebrates. There seems to be no possibility that the pseudofins could have developed as extensions of the lateral fin folds after the Gegenbauer theory.

No mention of the presence or development of the pseudofins has been found in the literature. This may be due to the fact that even when present, they are not readily apparent. However, under a dissecting microscope, the use of a small probe will quickly bring them into view.

The lengths which frigate mackerel attain before these pseudofins disappear and are replaced by a solid ridge is not definitely known. One specimen of 95 mm. from the Gulf of California had well-developed pseudofins. Mr. Charles B. Wade of the Philippine Fishery Program has kindly examined some juvenile *Auxis thazard* (140-231 mm., fork length) from Batangas, P. I. He finds that the rays of pseudofins are present but he believes that he detects an indication that these false fins are in the process of being lost when the fish is about 200 mm. in length.

In none of the juvenile *Auxis* or other scombroids examined by the writer has the center ridge of the caudal peduncle shown any fin structure. Yet the marks on the ridge seem to suggest that at sometime in the ontogeny of the species, this ridge must have carried a pseudofin similar to the paired structures developed laterally. Among other scombroids available for examination was a 113 mm. skipjack (*Katsuwonus pelamis*) from Costa Rica (previously reported by Eckles, 1949, p. 246, fig. 1). Since this specimen had been taken from the stomach of an adult tuna, some of the tail was partially digested. On one side it was possible to count 11 rays of the pseudofin, but on the opposite side there were 14. Mr. Wade examined three *Katsuwonus* from the Pilas Island group of the Sulu Archipelago, P. I. Two of the specimens, 18 and 22 mm., showed indication of the false fins. On the third specimen, 25.5 mm., development was just starting.

Mr. Wade also reports 14-rayed pseudofins on juvenile Philippine *Euthynnus affinis yaito* of a size range between 38 and 125 mm.

Three young specimens (17-63 mm.) of Costa Rican Spanish mackerel (*Scomberomorus sierra*) were examined (also previously reported by Eckles, 1949, p. 247, figs. 2 and 3). Strangely enough they showed no evidence of pseudofins on the peduncle although the largest specimen had the ridges slightly developed. More juveniles of this species are needed to determine whether the pseudofins develop late or are possibly absent at all stages.

Based on the four species reported upon herein, it would seem that most of the adult scombroids showing ridges on the side of the caudal peduncle probably pass through a pseudofin stage in their development.

REFERENCES

Eckles, Howard H.
1949. Observations on juvenile oceanic skipjack (*Katsuwonus pelamis*) from Hawaiian waters and sierra mackerel (*Scomberomorus sierra*) from the eastern Pacific. U. S. Fish and Wildlife Serv., Fishery Bull., vol. 51, no. 48, p. 245-256, 3 figs.

Fraser-Brunner, A.
1949. On the fishes of the genus *Euthynnus*. Ann. Mag. Nat. Hist., ser. 12, vol. 2, p. 622-627, 2 figs.
1950. The fishes of the family Scombridae. Ann. Mag. Nat. Hist., ser. 12, vol. 3, p. 131-163, 35 figs.

Kishinouye, Kamakichi
1923. Contributions to the comparative study of the so-called scombroid fishes. College Agric. Imperial Univ. Tokyo, Journ., vol. 8, no. 3, p. 293-475, 26 figs., 22 pls.

Wade, Charles B.
1949. Notes on the Philippine frigate mackerels, family Thunnidae, genus *Auxis*. U. S. Fish and Wildlife Serv., Fishery Bull., vol. 51, no. 46, p. 229-240, 10 figs.
1950. Juvenile forms of *Neothunnus macropterus*, *Katsuwonus pelamis* and *Euthynnus yaito* from Philippine seas. U. S. Fish and Wildlife Serv., Fishery Bull., vol. 51, no. 53, p. 395-404, 13 figs.

AGE AND LENGTH COMPOSITION OF THE SARDINE CATCH OFF THE PACIFIC COAST OF THE UNITED STATES AND CANADA IN 1950-51[1]

By Frances E. Felin,[2] United States Fish and Wildlife Service
Anita E. Daugherty and Leo Pinkas, California Division of Fish and Game

This is the fifth report on the age and length composition of the sardine catch off the Pacific Coast of the United States and Canada and covers the 1950-51 season. Previous reports have presented such data for the 1941-42 through 1949-50 seasons (Felin, Daugherty and Pinkas, 1950; Felin and Phillips, 1948; Felin, Phillips and Daugherty, 1949; Mosher, Felin and Phillips, 1949). There was no fishery off the British Columbia, Washington and Oregon coasts in this season. The interseason (summer) fishery in California was prohibited by law.

During 1950-51 sardines were landed at San Francisco, Moss Landing, Monterey, Morro Bay, Port San Luis, Santa Barbara, Hueneme, Los Angeles-Long Beach Harbor, Newport Beach and San Diego. Some of these fish were trucked to other ports for processing. All fish landed at San Francisco were processed there and appear in the San Francisco tonnages. Monterey totals include fish landed at that port, at Moss Landing and at Morro Bay. This combines ports south of San Francisco but north of Point Conception. All landings made south of Point Conception except San Diego were included with the San Pedro (Los Angeles-Long Beach Harbor) tonnages. San Diego totals include all landings at that port. Since Point Conception marks a division in oceanic conditions and separates two resultant fishing grounds, this grouping more accurately reflects the distribution of sardines in the ocean than would a grouping according to the place of processing.

The methods used in determining ages and sampling the catch have been described (Walford and Mosher, 1943a and b; Felin and Phillips, 1948). Previously, the sampling methods yielded a random selection of scale samples from the length frequency distribution of the fish. In the 1950-51 season the sampling methods were modified with the intent of improving their accuracy without a prohibitive increase in the amount of work required. The methods are similar to those used previously, with the following exceptions: Instead of five samples of 50 fish per week (in each port), 10 samples of 50 fish each were taken per week. Five samples were taken in the first half of the week (Monday through Wednesday) and five were taken in the last half (Thursday through Saturday). Instead of securing 10 scale samples at random with respect to fish length from each sample of 50 fish, one scale sample was taken at random from each

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[2] Published by permission of the Director, U. S. Fish and Wildlife Service.

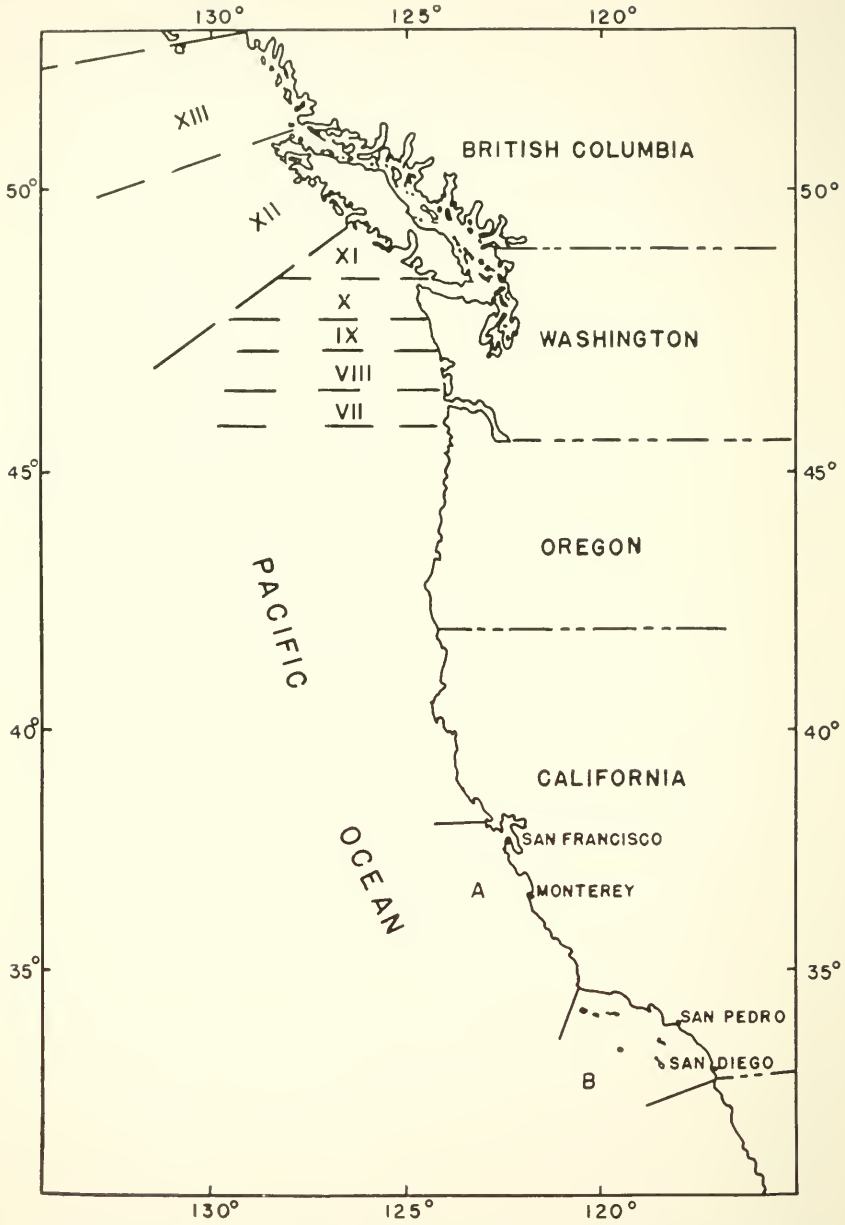

FIGURE 148. Sardine fishing areas. VII-XIII, areas in the Pacific Northwest fishery. A, San Francisco-Monterey fishing grounds. B, Southern California fishing grounds.

centimeter interval (i.e., 181-190, 191-200 mm., etc.) of fish length in the sample of 50 fish. Thus, the scale samples are random with respect to fish length *only* within each centimeter length stratum.

Tables 1 through 5 show, by sex and region of catch, the length frequency distributions of fish of each year class sampled in the 1950-51 season. The centimeter strata from which the scales were selected randomly with respect to fish length are indicated by the horizontal lines.

TABLE 1

Length Composition of the 1948 Year-Class, Age 2, 1950-51

Length, mm.	San Francisco			Monterey			San Pedro			California		
	M	F	T	M	F	T	M	F	T	M	F	T
178				1		1				1		1
180												
182												
184												
186							1	1	2	1	1	2
188					1	1	7		7	7	1	8
190				1	1	2	9	4	13	10	5	15
192				2		2	1		1	3		3
194					1	1	10	3	13	10	4	14
196				3	2	5	13	5	18	16	7	23
198				2	1	3	14	8	22	16	9	25
200				6	2	8	25	21	46	31	23	54
202	1		1	2	2	4	10	10	20	13	12	25
204				4		4	16	8	24	20	8	28
206	1	1	2	1	3	4	5	7	12	7	11	18
208	1	2	3	2	2	4	5	9	14	8	13	21
210	1	1	2	7	8	15	6	8	14	14	17	31
212				2		2	9	11	20	11	11	22
214	1	1	2	3	1	7	2	7	9	6	12	18
216				2	2	4	5	5	10	7	7	14
218					1	1	1	3	4	1	4	5
220					1	1		1	1		2	2
222							1	3	4	1	3	4
224				2		2		4	4	2	4	6
226					2	2		1	1		3	3
228							1	1	2	1	1	2
230												
232							1		1	1		1
234												
236					2	2					2	2
238												
240												
242					1	1					1	1
Totals	5	5	10	40	36	76	142	120	262	187	161	348

TABLE 2

Length Composition of the 1947 Year-Class, Age 3, 1950-51

Length, mm.	San Francisco			Monterey			San Pedro			California		
	M	F	T	M	F	T	M	F	T	M	F	T
190	1		1				1	1	2	2	1	3
192												
194							4		4	4		4
196				1		1	3	1	4	4	1	5
198				1		1	8		8	9		9
200	3	1	4	1		1	12	5	17	16	6	22
202				1	1	2	5	4	9	6	5	11
204	1		1	1	1	2	5	7	12	7	8	15
206				3	1	4	9	1	10	12	2	14
208	3	1	4	9		9	2	7	9	14	8	22
210		1	1	5	4	9	5	13	18	10	18	28
212				2	1	3	15	4	19	17	5	22
214				8	2	10	5	6	11	13	8	21
216	2	2	4	4	4	8	4	10	14	10	16	26
218	2	1	3	2	2	4	5	10	15	9	13	22
220	4	1	5	7	3	10	2	6	8	13	10	23
222	1	4	5	3	6	9	5	25	30	9	35	44
224		4	4	5	1	6	3	12	15	8	17	25
226		4	4	5	3	8		4	4	5	11	16
228	1		1	1	3	4	3	9	12	5	12	17
230		4	4	5	5	10	1	1	2	6	10	16
232	1	2	3	3	7	10		3	3	4	12	16
234	2	1	3	1	7	8	3	5	8	6	13	19
236				2	2	4		1	1	2	3	5
238	2	2	4	4	3	7		1	1	6	6	12
240		1	1		5	5		2	2		8	8
242	2	1	3	1	1	2		1	1	3	3	6
244				1		1				1		1
246					1	1					1	1
248				1		1				1		1
250					2	2					2	2
252												
254					2	2					2	2
Totals	25	30	55	77	67	144	100	139	239	202	236	438

TABLE 3

Length Composition of the 1946 Year-Class, Age 4, in 1950-51

Length, mm.	San Francisco			Monterey			San Pedro			California		
	M	F	T	M	F	T	M	F	T	M	F	T
196	1		1							1		1
198							1		1	1		1
200				2		2	2	1	3	4	1	5
202												
204				1		1	2		2	3		3
206				2		2	1	2	3	3	2	5
208	1		1	4		4	2	2	1	7	2	9
210	1	2	3	1	2	3	2	3	5	4	7	11
212	1	1	2	2	1	3	2	5	7	5	7	12
214				3	3	6	5	4	9	8	7	15
216	1	1	2	2	3	5	6	3	9	9	7	16
218	1	1	2	5	2	7	2	5	7	8	8	16
220		2	2	3	1	4	2	1	3	5	4	9
222	2		2	1	3	4	6	8	14	9	11	20
224	1	1	5	1	2	3	3	8	11	8	11	19
226				2	6	8	5	3	8	7	9	16
228		1	1	3	3	6	3	2	5	6	6	12
230				1	4	5	1	2	3	2	6	8
232		3	3	1	6	7		7	7	1	16	17
234		1	1	2	6	8	1	8	9	3	15	18
236	1	2	3	1	4	5	1	3	4	3	9	12
238				2	3	5		2	2	2	5	7
240					2	2	1	1	2	1	3	4
242					7	7	1		1	1	7	8
244				1		1	1	2	3	2	2	4
246	1	1	2		2	2		1	1	1	4	5
248	1		1		1	1				1	1	2
250					2	2					2	2
252				1		1				1		1
254		1	1	1		1				1	1	2
256												
258	1		1		1	1				1	1	2
Totals	16	17	33	42	64	106	50	73	123	108	154	262

TABLE 4

Length Composition of the 1945 Year-Class, Age 5, in 1950-51

Length, mm.	San Francisco			Monterey			San Pedro			California		
	M	F	T	M	F	T	M	F	T	M	F	T
198				1		1	1		1	2		2
200												
202												
204					1	1					1	1
206												
208					2	2					2	2
210					1	1					1	1
212							1		1	1		1
214					1	1	2		2	2	1	3
216	1		1	1		1	2	1	3	4	1	5
218		1	1	1		1				1	1	2
220				1	1	2	1		1	2	1	3
222				1	1	2	2	2	4	3	3	6
224					1	1	2	1	3	2	2	4
226								1	1		1	1
228				3	2	5	2	1	3	5	3	8
230					1	1		2	2		3	3
232	2		2		1	1	1	3	4	3	4	7
234	1		1	1		1				2		2
236				1	1	2	1	2	3	2	3	5
238				1		1		1	1	1	1	2
240												
242					1	1	1		1	1	1	2
244		1	1								1	1
246					1	1					1	1
248												
250												
252					1	1					1	1
254												
256				1		1				1		1
258					1	1					1	1
260												
266					1	1					1	1
Totals	4	2	6	12	18	30	16	14	30	32	34	66

TABLE 5

Length Composition of the 1944, 1943, 1942 and 1940 Year-Classes in 1950-51

Length, mm.	1944 year-class, age 6												1943 year-class, age 7			1942 year-class, age 8			1940 year-class, age 10		
	San Francisco			Monterey			San Pedro			California			California*			California*			California*		
	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
214				1		1				1		1									
216		1	1								1	1									
218																					
220	1		1				2		2	3		3									
222					1	1	1		1	1	1	2									
224					1	1					1	1									
226							1		1	1		1									
228								1	1		1	1									
230				1		1				1		1									
232								3	3		3	3									
234								1	1		1	1									
242				1		1				1		1	2		2						
244																					
246	1		1							1		1									
248																					
250																					
252	1		1							1		1									
254					1	1					1	1									
256																					
258					1	1					1	1					1	1			
260																					
262														1	1						
272														1	1					1	1
274																					
276														1	1						
286														1	1						
Totals	3	1	4	3	4	7	4	5	9	10	10	20	2	4	6		1	1		1	1

* Year-class represented in California only at Monterey.

Table 6 shows, by sex and region of catch, the mean length and standard error of the mean for each year class sampled in the 1950-51 season. These are simply based on the total samples for the season and are not weighted according to the relative proportions of the total catch made in the different lunar months. They are, however, of necessity weighted according to the length frequency distributions of the 50-fish samples.

TABLE 6

Mean Length and Standard Error of the Mean in Millimeters for Each Year-Class in the 1950-51 Season by Region of Catch

Year-Class	California					
	San Francisco		Monterey		San Pedro	
	M.	S.E.	M.	S.E.	M.	S.E.
1948						
Male	208	1.53	210	1.32	203	.46
Female	210	1.37	213	1.34	206	.46
Totals	209	1.06	212	.98	205	.36
1947						
Male	218	1.77	219	.87	208	.70
Female	223	1.24	223	.80	213	.62
Totals	221	1.05	220	.65	211	.49
1946						
Male	220	1.82	219	1.20	214	1.15
Female	222	2.21	224	.98	216	1.01
Totals	221	1.50	222	.80	215	.77
1945						
Male	222	4.90	224	2.06	217	2.23
Female	219	5.18	222	2.36	224	2.56
Totals	222	3.71	222	1.91	219	1.85
1944						
Male	224	7.61	223	5.01	221	1.01
Female	216		225	4.54	230	1.91
Totals	220	4.82	223	1.01	223	1.99
1943						
Male			242			
Female			274			
Totals			259			
1942						
Male						
Female			258			
Totals			258			
1940						
Male						
Female			272			
Totals			272			

TABLE 7

Calendar Dates of Lunar Months for the 1950-51 Season

"August"	July 30-August 27
"September"	August 28-September 26
"October"	September 27-October 25
"November"	October 26-November 24
"December"	November 25-December 23
"January"	December 24-January 22
"February"	January 23-February 20

Table 7 gives the calendar dates for the lunar months in the season.

Table 8 gives the numbers of fish, by region of catch, in each year class caught during the season. The number of fish caught was estimated from the total weight landed at each port in each week divided by the average weight of the fish during that period. These were summed by lunar months and ports. The apportionment of numbers of fish among the several year classes caught each lunar month at each port was slightly more complicated than previously, owing to the change in sampling methods. From the age data, the percentage of each year class within each centimeter length stratum was calculated. These percentages were then weighted according to the length frequency distributions of the 50-fish samples. The resulting percentages were used in allocating the number of fish among the different year classes.

Scale samples and fish measurements were obtained at San Francisco by Carl W. Walser, at Monterey by Leo Pinkas and at San Pedro by Anita E. Daugherty. Age determinations were made by the three authors. We wish to acknowledge with thanks the assistance of Mr. Walser and of Mrs. Madalyn B. Murray in the laboratory. Special thanks are due to Mr. T. M. Widrig for his valuable advice in connection with sampling problems.

TABLE 8

Age (Year-Class) Composition of the Sardine Catch in the 1950-51 Season

(Numbers of fish are given in thousands, i.e., 000 omitted)

	Catch		Number of fish by age (year-class)							
			2	3	4	5	6	7	8	10
	Tons	Number	1948	1947	1946	1945	1944	1943	1942	1940
San Francisco										
"August"	12,445	67,885	5,363	36,658	20,298	3,258	2,308			
"September"	281	2,124	1,189	765	170					
Totals, San Francisco	12,726	70,009	6,552	37,423	20,168	3,258	2,308			
Monterey										
"August"	8,463	17,545	6,656	20,444	14,264	5,230	951			
"September"	3,275	19,109	3,612	9,765	3,038	2,198	382	95		19
"October"	4,749	29,737	2,111	9,397	15,671	1,219	1,249		60	
"November"	6,991	47,330	16,139	13,442	13,631	2,810	1,278			
"December"	6,938	14,516	6,677	20,388	15,103		1,781	267		
"January"	1,661	12,385	2,229	5,202	1,954					
Totals, Monterey	32,077	200,622	37,124	78,638	66,961	11,517	5,641	362	60	19
San Pedro										
"October"	116,708	900,290	448,341	359,216	78,325	12,601	1,801			
"November"	80,168	626,152	353,150	179,706	79,521	9,392	1,383			
"December"	69,440	501,384	182,587	217,891	84,736	19,167				
"January"	32,159	234,335	74,753	93,265	49,445	16,872				
"February"	4,339	31,546	8,707	15,205	5,741	505	1,388			
Totals, San Pedro	302,814	2,296,707	1,067,541	865,286	297,768	58,540	7,572			
San Diego*	2,931	22,231	9,848	8,426	3,179	645	133			
Grand totals	350,548	2,589,569	1,121,365	989,773	388,376	73,960	15,654	362	60	19

* All values at San Diego, except tons landed, were prorated from San Pedro totals.

REFERENCES

Felin, Frances E., Anita E. Daugherty and Leo Pinkas
1950. Age and length composition of the sardine catch off the Pacific Coast of the United States and Canada in 1949-50. Calif. Fish and Game, vol. 36, no. 3, pp. 241-249, 1 fig.

Felin, Frances E., and Julius B. Phillips
1948. Age and length composition of the sardine catch off the Pacific Coast of the United States and Canada, 1941-42 through 1946-47. Calif. Div. Fish and Game, Fish Bull. 69, 122 p., 1 fig.

Felin, Frances E., Julius B. Phillips and Anita E. Daugherty
1949. Age and length composition of the sardine catch off the Pacific Coast of the United States and Canada in 1948-49. Calif. Fish and Game, vol. 35, no. 3, pp. 165-183, 1 fig.

Mosher, Kenneth H., Frances E. Felin and Julius B. Phillips
1949. Age and length composition of the sardine catch off the Pacific Coast of the United States and Canada in 1947-48. Calif. Fish and Game, vol. 35, no. 1, pp. 15-40, 1 fig.

Walford, Lionel A., and Kenneth H. Mosher
1943a. Studies on the Pacific pilchard or sardine (*Sardinops caerulea*). 2. Determination of the age of juveniles by scales and otoliths. U. S. Fish and Wildlife Service, Special Sci. Rept. no. 20, 19 p., 32 figs.
1943b. Studies on the Pacific pilchard or sardine (*Sardinops caerulea*). 3. Determination of age of adults by scales, and effect of environment on first year's growth as it bears on age determination. U. S. Fish and Wildlife Service, Special Sci. Rept. no. 21, 29 p., 6 figs.

NOTES

THE WHALE SHARK, *RHINEODON TYPUS*, OFF NORTHERN BAJA CALIFORNIA

While fishing a few miles south of the United States-Mexico boundary near South Island of Los Coronados, Baja California, on January 31, 1951, the passengers aboard the sportfishing boat *Collerer* spotted a school of sardines jumping wildly at the surface. Mr. Offie Collins, skipper and owner of the *Collerer* which operates out of San Diego, moved the boat directly over the center of activity. A large shark was moving leisurely just beneath the surface and seemed to be "feeding on the sardines." Collins stayed near the shark for about 15 minutes and "bumped it with the side of the boat several times for the benefit of the passengers." The shark was described as about 20 feet long, brownish in color with yellowish spots, from the size of a quarter to that of a saucer, all over its body. The dorsal fin was rounded and the gill slits extended from high on the back nearly to the throat on the underside. Unquestionably this was a whale shark, *Rhincodon typus*.

The present locality some 30 miles south of San Diego is over 750 miles north of any previous record on this coast. Gudger (1935, Proc. Zool. Soc. London, p. 863-893) has recorded this species from Cape San Lucas, Baja California, where it is a common sight to California tuna fisherman.—*John E. Fitch, Bureau of Marine Fisheries, California Division of Fish and Game, February, 1951.*

PACIFIC COD OFF CENTRAL CALIFORNIA

A Pacific cod (*Gadus macrocephalus*), 25½ inches total length, was captured off Pt. Sur, about 25 miles south of Monterey, California, on February 15, 1951. The specimen was taken by the drag boat *Liberty*, Captain F. M. Rhoades, while otter-trawling for chilipepper and bocaccio rockfish in 100 fathoms. The specimen was taken to the General Fish Corporation, Monterey, where is was observed by the author. Captain Rhoades, who had previously fished at Eureka, California, stated that he had caught an occasional Pacific cod in his drag net while operating in the Eureka region. In "California Fish and Game," vol. 36, no. 4, p. 439, October, 1950, the author records several specimens taken in Northern California. The present record extends the southern range of this species another 300 miles.—*J. B. Phillips, Bureau of Marine Fisheries, California Division of Fish and Game, February, 1951.*

RETIREMENT OF HARRY COLE

Harry Cole, Fish Hatchery Foreman, Yuba River Hatchery, retired from the service on April 30, 1951. He was first appointed Fish Hatchery Foreman on December 3, 1928, with the former Bureau of Fish Culture and was stationed at the Feather River Hatchery. He was later transferred to the Basin Creek Hatchery and since October, 1941, has been in charge of the Yuba River Hatchery, Sierra County. During the past two seasons Mr. Cole has been temporarily stationed each spring at the Idlewild Hatchery, Reno, Nevada, to assist in the California-Nevada cooperative program for the introduction of Kokanee into Lake Tahoe. Before coming to the Division of Fish and Game he was with the State of Oregon, Fish and Game Department. Our best wishes to Harry for a long and happy retirement.—*A. C. Taft, Chief, Bureau of Fish Conservation.*

REVIEWS

Wildlife Management

By Ira N. Gabrielson; The Macmillan Company, New York, 1951; xii + 274p., 40 illus., 8 tables. $4.50.

This title may confuse readers of this journal for two reasons. Not long ago a book with nearly the same title but written by another author was presented to the public and reviewed herein (vol. 35, 1949, p. 205). In the second place Ira Gabrielson, who was director of the U. S. Fish and Wildlife Service for eleven years, has defined "wildlife" to mean not only mammals and birds but fish as well. This authoritative innovation may now give John Doe a more concise meaning of the term, which he understood generally to mean only land animals. The book is aimed to help those interested in improving the position of wildlife, and the author appraises current practices, shows the need for repeated checks on techniques, and emphasizes the use of balanced management programs. There are several definitions of management in the book. Basically, wildlife management is a two-fold program to (a) maintain and utilize a resource and (b) at the same time modify human activities affecting that resource.

In explaining these phases Dr. Gabrielson does not plead on his knees for wild life. His appraisals and discussions are straightforward commentaries on the principal features of a relatively new profession. If a credo is apparent, it concerns public participation in a national wildlife program. His ideas on this matter are presented briefly and directly to the point. Scattered through the book are succinct key sentences. If these sentences and certain picture-captions were to be arranged systematically, both would together serve as a primer on wildlife management. The photographs are excellent, but they would have served a better purpose arranged in the same sequence as are the topics. Technical terms are almost wholly absent; the book is more effective because of this. In general each chapter is a complete discussion of a topic in this order: history, function, limitations, and appraisal. A list of pertinent and basic references follows each chapter and can be advantageously used by those who will read more.

A very pressing need for better methods is evident, says the author, in biological research in both game and fisheries management, in public education, and in state administration. Indeed, this comment is made so often one may wonder where progress has been made at all. Minor discrepancies occur. At first mention neither the location nor the significance of the events at Horseshoe Lake, Illinois, are explained. The tables in chapter seven, "Artificial Propagation," seem to serve no immediate purpose. A hint is given that European management methods for big game are more effective, but this point is not enlarged.

Such criticisms of "Wildlife Management" are picayunish. The book instantly answers the need for a broad critique of management practices used today. It is particularly well written and will be a standard source of information for citizen, legislator, student, and biologist.—*Robert L. Eberhardt, California Division of Fish and Game.*

Geography of the Pacific

Otis W. Freeman, Editor; John Wiley & Sons, Inc., New York, 1951; xii + 573 p., 156 figs. $10.

Here is an excellent account of the Pacific, its lands and its peoples. There has been a definite need for a comprehensive reference of this sort, for as the Pacific continues to grow in world importance so does the demand for information about it. The authors are not concerned with the bordering American and Asiatic mainlands nor do they consider the home islands of Japan—existing references are quite adequate—but every place else from Australia to such currently unimportant pinpoints as Clipperton Island is described in as much detail as knowledge and space permit. Thirteen men contributed to the volume, most of them representing Pacific Coast and Hawaiian institutions.

The first three of the nineteen chapters treat the physical geography, native peoples, and explorations of the entire Pacific, and the last presents a survey of trade, transportation and strategic places. Those between discuss first and most extensively Australia and then the island groups. These chapters follow the same general scheme, and the book as a whole is cohesive, something which cannot always be said where multiple authorship is involved. Physical geography, climate, mineral resources, flora and fauna, agriculture, fisheries, commerce, trade and industry, the inhabitants, their history and government: these all receive consideration in rough proportion to their importance. Some of the relatively minor topics are skipped over once in a while, but such derelictions are infrequent and not serious.

The book is recommended highly to anyone interested in the Pacific, be his interest academic, commercial, or simply the result of living near this ocean or having sailed it. Well illustrated with photographs and maps, attractively printed and bound, it will make a handsome as well as a valuable addition to one's library.—*Phil M. Roedel, California Division of Fish and Game.*

The Sea Shore

By C. M. Yonge; Collins, London, 1949; 311 p., 61 color and 62 black and white photographs, 88 text figures, $5.

Americans have frequently commented on the knack of British scientists in being both willing and able to write books of high quality which serve layman and fellow scientist alike. Such a comment is very much in order here. Professor Yonge not only has a full command of his subject but he writes delightfully.

The intertidal area of Britain encompasses highly varied environments reflecting the influence of both warm and cold waters on sandy beaches, rocky coasts and estuaries. It has been the object of intensive study for many years, and, consequently, there is a great fund of knowledge about its habitats and the animals and plants living in them. The essence of that knowledge forms the subject matter of the book.

In his introductory chapters, Professor Yonge presents general information which provides his readers with the background necessary for an understanding of the shore. He tells something of the history of studies of the sea shore in Britain, describes the kinds of animals and plants to be found, relates a bit of oceanography so that one can appreciate the influence of the open ocean on the shore and its denizens, and explains how the shore is affected physically by the impact of the ocean upon it.

Most of the book deals with specific habitats or with groups of animals; one chapter is devoted to marine plants. These chapters tell the story of life as it exists within the limited area of the shore, of the gradations and differences one will find as he explores the various zones which lie between high water line and low. They tell of the adaptations of the inhabitants, their relationships with each other and with their environments—in short, the ecology of this meeting place of land and ocean. The locale is Britain but the principles are as valid in California.

The closing sections discuss the factors, particularly water temperature, which limit the ranges of intertidal species and which may account for fluctuations in abundance, and the uses to which shore products are or can be put. It will probably come as a surprise to many readers in this country, most of whom relish a wide variety of seafoods, that the English make relatively little use of these resources. There is an appendix which tells briefly of major references and an index and glossary.

The many illustrations are outstanding. The color photographs are superb and unquestionably comprise the book's most striking feature. They tend to overshadow the black-and-white photographs which by themselves would be sufficient cause for admiration.

Anyone interested in natural history should own this book.—*Phil M. Roedel, California Division of Fish and Game.*

Fishing in the West

By Arthur H. Carhart; The Macmillan Company, New York, 1950; viii + 144 p., illustrated. $4.50.

This book turns out to be little more than a compilation of chapters each of which might have appeared alone in a monthly outdoor magazine. Most of them start off in somewhat the following manner: "Old man Colby was sort of a recluse," or "It was time to head in to the little camp fire." The purpose of the book is to stimulate the imagination of the angler confined to the eastern side of the Mississippi River rather than to supply much useful information to the western fisherman. As so often happens under these circumstances the atypical and unusual situation is presented rather than the common experience, such as the following: "His rod was one to handle a torpedo line, a strong 11 footer, and the fly was Lady Mite, No. 14." It is hoped that no inexperienced angler follows this advice literally in any of our California waters.

The chapters on the various species are not too accurate and some misidentification is evident. For example, "Kern River trout" are caught in Clear Creek, Colorado, a badly polluted stream near Denver, and six separate references are made to catching "silver salmon" in the Missouri River at Helena, Montana.

This book cannot be recommended to any student of fisheries, but it will be good entertainment for any apartment-bound sportsman. It makes an especially strong case for habitat improvement and condemns "the criminal waste of money on hatcheries"—a thought which should cause considerable comment among some sportsmen.—*R. M. Paul, California Division of Fish and Game.*

REPORTS

FISH CASES

January, February, March, 1951

Offense	Number of arrests	Fines imposed	Jail sentences (days)
Abalone: Closed season; no license; undersize; out of shell; overlimit; failure to show license on demand; diving in District 19A; taking for commercial purposes in District 19A; closed area	151	$4,351.50	
Angling: No license; possessing gaff within 300 feet of stream; using another's license; fishing in closed stream; snagging; 2 lines; 2 poles; failure to show license on demand; spearing fish within 100 feet of lower side of Mendota Dam; making false statement to secure license; night fishing; using 7 poles; angling in closed district; set lines; treble hook	238	3,715.00	281
Barracuda: Selling undersize	1	12.50	
Bass, Black: Closed season; no license	2	30.00	
Bass, Striped: Possession on commercial boat; 2 lines; overlimit and sale of undersized; possession in restaurant; no license; undersize; taking at night; buying	42	1,192.50	
Bluegill: Closed season	7	255.00	
Carp: Taking with gaff and clubs; no license	4	155.00	
Catfish: 2 lines; taking other than by angling; selling undersize; possessing undersize; no license; operating set line	10	160.00	
Clam, Cockle: No license; overlimit; undersize	33	1,165.00	17
Clam, Gaper: No license; overlimit	4	90.00	
Clam, Pismo: Overlimit; undersize; failure to show on demand; no license; out of shell; selling; digging after hours; taking after hours; night clamming	114	3,723.00	90
Clam, Washington: No license; overlimit	2	60.00	
Commercial: No commercial license; drag net in 13½ fathoms (Monterey); failure to obtain fish packer's license; failure to keep records; operating purse seiner in District 19A; illegal use of round haul net in closed area; taking fish with purse seine in District 118.5; operating purse seiner in District 118.5; failure to keep and return log record on drag boat; selling fish without commercial license; over 500 lbs. crab on drag boat; no dealer's license; failure to issue fish receipts; selling short catfish; possessing undersize crabs; using drag net in less than 50 fathoms; dragging in less than 25 fathoms in District 17	157	6,319.00	373
Crab: Undersize; taking undersize female for sale	2	225.00	
Crappie: Closed season	1	25.00	
Frog: Closed season	4	145.00	
Lobster: Pulling lobster traps; undersize; possessing undersize and resisting arrest; operating traps in closed area	12	570.00	
Pollution: Sawdust in stream; oil; sawdust and trash	3	100.00	
Salmon: No license; spearing within 300 feet of closed stream; attempting to take and taking on spawning beds	4	170.00	
Shad: Closed season	1	50.00	
Sturgeon: On commercial boat	1	37.50	
Trout: Snagging; no license; shooting with rifle; closed season; overlimit; using trout roe; fishing in closed stream; possessing steelhead; importing without tags; snagging with triple hooks; possessing trout and gaff hook in closed area; spearing	21	885.00	
Yellowtail: Selling	1	12.50	
Totals	815	$23,448.50	761
Seizures: Abalone		308.05	
Crab		49.00	
Sardine		3,618.75	
Grand total		$27,424.30	

GAME CASES

January, February, March, 1951

Offense	Number of arrests	Fines imposed	Jail sentences (days)
Bear: Closed season	1	$10.00	
Beaver: Closed district	3		200
Coot: Closed season; taking with .22 rifle; no license; late shooting	8	165.00	17½
Deer: Closed season; attempting to take overlimit; taking doe, spike buck, forked horn; illegal possession; unauthorized possession of doe; failure to tag; failure to fill out tag; night hunting; use of flashlight, artificial light; possession of spotlight while hunting	47	4,962.50	280
Deer meat: Possession and purchase of unstamped meat; possessing illegal meat; closed season; possession and sale; possessing unstamped meat	24	2,000.00	90
Dove: Closed season; unplugged gun; bringing from Mexico in closed season; overlimit	6	316.00	
Duck: No license; possessing gun in refuge and late hunting; closed season; overlimit; late shooting; bringing overlimit from Mexico; unplugged gun; using .22 rifle and no license; shooting from powerboat; undeclared ducks; taking from auto; attempting to take at night; operating powerboat for shooters; transferring license tags; early shooting; shooting in refuge; failure to show license on demand	207	6,487.50	
Goose: Closed season; possession of gun in refuge; late hunting; no license; hunting on refuge; taking with .22 rifle; overlimit; shooting from motorboat; bringing overlimit from Mexico; improperly plugged gun	39	1,115.00	
Hunting: Using spotlight; possession of gun in refuge; possession of gun and light at night; no permit; no back patch in cooperative area; night hunting; falsifying license; discharging gun in refuge; no license; spotlighting; hunting on restricted zone; unplugged gun; early shooting; hunting in Federal Refuge	72	1,920.00	
Nongame birds: Taking meadow lark, seagulls; shooting at meadow lark, redtail hawk, sparrow hawk, monkey-faced owl, woodpecker	9	125.00	
Pheasant: Closed season; taking hen; early shooting; shooting from powerboat; failure to tag; hunting and possessing in closed season; no game breeder's license; taking in closed zone of cooperative area; unplugged gun; possessing without tags; taking with .22 rifle	28	1,165.00	180
Pigeon: Overlimit; closed season	2	75.00	
Quail: Closed season; overlimit; possession of gun and light in quail area at night	16	765.00	
Rabbit: Taking at night in closed season; no license; attempting to take in closed season; unplugged gun; transfer of hunting license; shooting from public road; night hunting; hunting with another's license; taking cottontails in closed season; spotlighting and shooting from car	117	2,905.00	
Shore birds: Shooting protected shore birds	3	75.00	
Swan: Taking wild swan	2	100.00	
Totals	584	$22,186.00	767½

SEIZURES OF FISH AND GAME

January, February, March, 1951

Fish:	Pounds		Number
Abalone	2	plus	3,122
Barracuda	191		
Bass, Black			37
Bass, Striped	135	plus	38
Bass, White Sea	9,818		
Bluegill			91
Carp			201
Catfish	15	plus	65
Clam, Cockle	416	plus	8,675
Clam, Gaper			76
Clam, Pismo			2,123
Clam, Washington			63
Crab	870	plus	49
Crappie			13
Frog			25
Lobster	47	plus	113
Salmon	65½	plus	3
Sardine	270,500		
Shad			6
Sturgeon			2
Trout	35	plus	44
Yellowtail	304		

Game:			
Beaver			1
Beaver, hides			4
Coot			13
Deer	259	plus	22
Dove			83
Duck			505
Goose			72
Nongame birds			9
Pheasant			18
Quail			62
Rabbit			84
Squirrel			1
Swan			2

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